DUPLICATE

METEOROLOGICAL OFFICE
15DEC1994
LIBRARY

Forecasting Research

Forecasting Research Division
Technical Report No. 128

IMPACT OF A NEW GRAVITY WAVE DRAG SCHEME AND OROGRAPHIC ROUGHNESS IN THE UNIFIED MODEL. II . PARALLEL SUITE TRIAL FOR GLOBAL MODEL AND LIMITED AREA MODELS

by

C. A. Wilson and O. Hammon

November 1994

Meteorological Office
London Road
Bracknell
Berkshire
RG12 2SZ
United Kingdom

ORGS UKMO F

National Meteorological Library
FitzRoy Road, Exeter, Devon. EX1 3PB

FORECASTING RESEARCH TECHNICAL REPORT NO 128

IMPACT OF A NEW GRAVITY WAVE DRAG SCHEME AND OROGRAPHIC ROUGHNESS IN THE UNIFIED MODEL. II. PARALLEL SUITE TRIAL FOR GLOBAL AND LIMITED AREA MODELS

by

C. A. Wilson and O. Hammon

NOV 1994

© Crown Copyright 1994

Forecasting Research Division
Meteorological Office
London Road
Bracknell
Berks
RG12 2SZ

This Technical Report has not been published. Permission to quote it must be obtained from the Head of Numerical modelling, Forecasting Research Divison.

IMPACT OF A NEW GRAVITY WAVE DRAG SCHEME AND OROGRAPHIC ROUGHNESS IN THE UNIFIED MODEL. II. FIRST PARALLEL SUITE TRIAL FOR GLOBAL AND LIMITED AREA MODELS

CONTENTS

1. INTRODUCTION
2. OBJECTIVE VERIFICATION - GLOBAL MODEL
3. SUBJECTIVE ASSESSMENT - GLOBAL MODEL
4. OBJECTIVE VERIFICATION - LIMITED AREA MODEL
5. SUBJECTIVE ASSESSMENT - LIMITED AREA MODEL
6. FINAL REMARKS
7. ACKNOWLEDGEMENTS
8. APPENDIX-EXTENDED TRIAL OBJECTIVE VERIFICATION

1. INTRODUCTION

This technical report contains the results and assessment of the first parallel suite trial of the new gravity wave drag scheme and inclusion of a representation of orographic roughness in the unified model. The details of the schemes and tests for the global model at other seasons of the year are described in **Technical Report 127** (Milton et al, 1994). The global forecast and limited area model versions were run in parallel to the operational suite from 26/10/94 to 14/11/94. A fully independent assimilation cycle was maintained for the parallel global model and forecasts to T+120 were made once per day from the 12 UTC main analysis time. The limited area model 4-cycle assimilation (15,18,21,00 UTC) was intermittently started from the 12 UTC analysis and forecasts to T+36 were made once per day from its own 00 UTC analysis. The operational verification packages were included to give comparable statistics from the parallel and operational suites.

The trial was continued from 15/11/94 to 23/11/94 with an addition set of corrections for the elimination of superadiabatic profiles (see **Technical Report 125** (Wilson et al, 1994)). These corrections have a generally very small or neutral impact on the verification, and summary tables of the verification for the whole period 31/10/94-23/10/94 are given in the appendix.

Conclusions are given at the end of each of sections 2,3,4, and 5, with the final summary in section 6.

2. OBJECTIVE VERIFICATION - GLOBAL MODEL

The analyses and forecasts were verified against observations (sondes and synops) for

the period 31/10/94 to 14/11/94. Verification was also performed against analyses, each suite was verified against its own analyses for the same period. Time-mean results will mostly be discussed here . Results for forecast times T+0, T+24, T+48, T+72, T+120 and for areas "2", N. Hemisphere to 30N ("200"), Tropics 30N-30S ("300") and S. Hemisphere from 30S ("400") will be given.

2. 1 RMS ERRORS -OVERALL SUMMARY

TABLE 2.1 summarises the objective scores for the N. Atlantic region (area 2) and extratropical N. Hemisphere. It shows the percentage changes in rms errors for heights, temperatures , vector winds (8 levels each) , relative humidity (3 levels) and 3 surface fields. A negative value shows the trial to be an improvement. Column and surface-means are also shown.

Height scores show a general improvement from T+48 on. Rms height errors are improved by 3-4% at T+72 and are substantially better by 9-10% at T+120 for area 2 and by 5% typically for N. Hemisphere. There are similarly large improvements in temperature scores particularly at T+120, when the mean improvement is ~5-6%, and at 200hPa where the improvements are up to 10%. Winds are mostly better, with substantially smaller errors near the surface at 850hPa and at jet levels . Again the largest improvements are at T+120. The upper levels at 200 and 100hPa are improved at all forecast times by ~3% and 10-15% respectively. This reflects the smaller gravity wave drag in the stratosphere noticed in earlier tests, which is an improvement which the modifications were aimed at since the gravity wave drag was too strong here due to insufficient gravity wave stress being absorbed at lower levels (see Technical Report 127). Relative humidities are also mostly better.

Rms errors of surface pressure are greatly improved by 2-3% at T+72 and by 6-7% at T+120. Scores for surface temperatures and winds are also much better for all forecast and analysis times and are up to 8% and 13% better respectively at T+120.

Although the scores are mostly much improved at the longer forecast ranges there are a few errors at T+24 which are worse in the trial. In particular the 500 and 700hPa heights have deteriorated by 3-5%. Breaking these results down into 10 degree latitude bands shows the bands north of 50N generally verify as well or better for the trial and that the largest deterioration is in the 30-40N band. It would appear that the worsening in the tropics (see below) is also affecting the sub-tropics in the short period forecasts. Moreover, if the results are broken down in terms of geographical areas the trial verifies better against N. American sonde stations but worse against European sonde stations (not shown). The impact at T+24 therefore appears rather mixed and may be affected by the synoptic situation for the particular period of the trial. The worsening should not cause undue concern, particularly since the T+48 scores for the N. Hemisphere are better for the trial and verification against analyses (**TABLE 2.4**) at T+24 also show the trial to be better.

Overall there is a significant reduction in rms errors for most parameters. Taking changes greater than 1%, the number of scores from **TABLE 2.1** for which the trial was better are given

%RMS CHANGE (TRIAL-OPERATIONAL) PERIOD 31/10/94-14/11/94											
VERIFICATION AGAINST OBSERVATIONS											
	T+0	T+24	T+48	T+72	T+120		T+0	T+24	T+48	T+72	T+120
AREA	2					AREA	200, N Hem to 30N				
HEIGHTS						HEIGHTS					
850	1.5	0.2	-3.5	-3.8	-10.2	850	0.8	-3.4	-6.7	-4.3	-5.6
700	2.3	5.1	-0.5	-2	-11.6	700	1.7	2.9	-2.3	-2	-5
500	1	2.7	1.6	-1.2	-11.3	500	0.7	4.8	-0.3	-1.5	-5.2
300	0	-3.3	-2.3	-3.4	-9.9	300	-0.1	0.2	-1.5	-3.2	-4.8
250	0	-3.2	-1.2	-3	-9.4	250	0.5	0.8	-0.7	-2.6	-4.7
200	0	-1.8	-0.8	-2	-8.2	200	0.1	1.8	-0.4	-1.8	-4.2
100	0.3	-2.3	-2.8	-4.2	-7.9	100	-0.3	-0.3	-3.9	-4.6	-5.8
50	-1.1	-1.8	-2.3	-3.3	-4.5	50	-0.4	-4.3	-7.7	-8.5	-7.8
Mean	0.5	-0.6	-1.5	-2.9	-9.1	Mean	0.4	0.3	-2.9	-3.6	-5.4
TEMPERATURES						TEMPERATURES					
850	1.2	3.2	3.8	-2.8	-7.1	850	-0.4	1.3	0.8	1	-6.2
700	-0.7	-1.9	-2.8	-2.2	-8.1	700	-0.5	-2.4	-1.6	-0.9	-5.5
500	-1.6	-3.1	-0.7	-2.2	-5.7	500	0.3	-1.3	-1.6	-1.6	-2.9
300	-1.5	4.4	3.1	4.8	0.9	300	-2.1	-0.4	-0.4	0.5	-0.2
250	1.9	-0.3	-0.8	1.9	-5.5	250	0.5	-1.7	-3.5	-1.7	-3.5
200	0.5	-6.7	-6.3	-6.9	-10	200	0.1	-7.3	-7.7	-8.6	-9.2
100	-0.6	-4.5	-10.7	-10	-7.3	100	-0.2	-5	-9.6	-10.2	-9.4
50	0.5	-1	0	-0.4	-3.6	50	0.3	-1	-2.9	-5.3	-4.5
Mean	0	-1.2	-1.8	-2.2	-5.8	Mean	-0.2	-2.2	-3.3	-3.3	-5.2
WINDS						WINDS					
850	1.8	0.4	-2.3	-6.7	-14.1	850	2.5	-2.9	-4.8	-5.8	-11
700	0.1	3	0.4	-2.2	-12.5	700	0.8	0.3	-1.3	-2.6	-7.7
500	0.3	3.4	1.9	-0.6	-10.4	500	0.3	1.5	0.1	-1.4	-6.3
400	0.2	1.4	1	-0.7	-9.6	400	-0.1	0.4	-0.4	-1.7	-5.6
300	-0.9	-2	-0.3	-1.2	-8.6	300	-0.6	-2.1	-0.3	-1.8	-4.5
250	-1	-0.9	-0.5	-0.7	-7.7	250	-0.7	-1.3	-0.3	-1.2	-3.8
200	-0.9	-3.7	-3.2	-3.1	-7.4	200	-0.3	-3	-2.1	-2.8	-3.2
100	-0.8	-10	-13.4	-13	-13.4	100	-1.6	-15.1	-17.8	-16.9	-11.8
Mean	-0.2	-1.1	-2	-3.5	-10.5	Mean	0	-2.8	-3.4	-4.3	-6.7
RH						RH					
850	0.2	-1.1	-1.3	-2.3	-3.1	850	-1.4	-0.9	-1.1	-2	-2.9
700	0.5	0.9	-1.6	-2	-5.1	700	-0.3	-0.8	-2.6	-1.9	-3.6
500	-0.5	-0.3	-1.5	-0.2	-6.1	500	-0.4	-1.6	-1.9	-1.8	-4.4
Mean	0.1	-0.2	-1.5	-1.5	-4.8	Mean	-0.7	-1.1	-1.9	-1.9	-3.6
SURF						SURF					
-pmsl	-2.6	1.3	-1.5	-2.2	-7.3	-pmsl	-0.6	-1.1	-3.6	-2.6	-6.1
-temp	-4.8	-5.9	-6.9	-4.6	-7.4	-temp	-9.1	-9.4	-9.2	-7.4	-8.2
-wind	-0.3	-2.9	-4.9	-6.8	-11.5	-wind	-3.2	-7.4	-8.7	-10.1	-13.2
Mean	-2.6	-2.5	-4.4	-4.5	-8.7	Mean	-4.3	-6	-7.2	-6.7	-9.2
Mean all	-0.2	-1	-2	-2.9	-8.1	Mean all	-0.5	-2	-3.5	-3.8	-5.9

TABLE 2.1

%RMS CHANGE (TRIAL-OPERATIONAL) PERIOD 31/10/94-14/11/94											
VERIFICATION AGAINST OBSERVATIONS											
	T+0	T+24	T+48	T+72	T+120		T+0	T+24	T+48	T+72	T+120
AREA	300, Tropics 30N to 30S					AREA	400, S Hem from 30S				
HEIGHTS						HEIGHTS					
850	0.4	3.4	-4.1	1.8	1.6	850	2.2	-5.9	-6.3	-8.7	-1.6
700	0.7	15	16.4	24	21.3	700	1.8	-4.2	-4.9	-7.5	-1.6
500	1.4	10.5	12.1	14.8	13.9	500	-1.1	-2.5	-2.5	-2.9	-2.1
300	0.7	8.6	10.8	12.3	11.8	300	-1.2	-1.8	-2.2	-1.7	0.8
250	1.2	8.3	10.6	11	10.5	250	-1.3	-2.2	-1.8	-1.6	0.3
200	0	5.9	7.1	7.6	7.6	200	-0.3	-1.9	-1.7	-1.6	-0.8
100	0.4	1.4	0.1	-0.2	-0.1	100	0.7	1.4	0.2	-1.2	-1.9
50	-0.2	-0.9	-1.9	-2.4	-2	50	0	-1	-1	-4	-3.4
Mean	0.6	6.5	6.4	8.6	8.1	Mean	0.1	-2.3	-2.5	-3.6	-1.3
TEMPERATURES						TEMPERATURES					
850	0.4	0.9	-2.5	-1.1	-2.5	850	-0.8	-1.5	-1.2	0.9	-0.9
700	0.6	0.2	-0.7	-1	-3.9	700	-0.8	3	3.2	2.1	0.5
500	-0.5	0.4	0.3	-1.1	-2.8	500	1.2	0.3	-0.8	0.6	3.3
300	0.8	1	-0.7	-0.2	-3.3	300	-2.2	-4.6	-5.6	1.8	1.1
250	0.4	0.1	-1.8	-1.9	-4.3	250	-0.9	-2.5	-3.7	-2.3	-0.9
200	0.1	-1.2	-2.6	-1.9	-2.7	200	0.4	-1	-1.6	-3.8	-0.5
100	0.4	0.9	0.3	0.3	-1.3	100	0	-2.8	-2.8	-2.9	-3.4
50	0.9	-0.5	0.8	0.7	-0.8	50	1.4	0.2	-0.4	-2	-1.7
Mean	0.4	0.2	-0.9	-0.8	-2.7	Mean	-0.2	-1.1	-1.6	-0.7	-0.3
WINDS						WINDS					
850	1.5	-4.3	-6	-5.5	-4.4	850	4.2	-1.6	-4.4	-3.9	-5.7
700	1.6	-1.3	-2.3	-3.1	-0.6	700	1.4	-0.1	-2.3	-2.7	-3.8
500	-0.6	-2.2	-2.8	-2.3	-1.9	500	-0.1	-1.4	-3.3	-2.4	-1.1
400	-0.3	-0.9	-0.4	-0.6	0	400	-0.3	-1.9	-3.2	-0.9	1
300	0.8	-0.2	-0.5	0.6	0.5	300	-1.4	-2	-3.2	0.2	1
250	0.2	0.3	0.1	0.1	0.9	250	-1.1	-2.1	-1.6	0.2	0.1
200	0.8	0.4	0.3	0.8	-0.4	200	-0.4	-2.3	-1	1.4	0.4
100	-0.5	-1.2	-2.2	-3.2	-4.1	100	-1.3	-2.8	0.1	1.2	0.7
Mean	0.4	-1.2	-1.7	-1.6	-1.2	Mean	0.1	-1.8	-2.4	-0.9	-0.9
RH						RH					
850	0.8	-1.5	-2.9	-0.5	2	850	-5.8	-1.7	-0.2	1	0
700	0.2	-0.5	-1.4	-1.2	-1.4	700	-0.3	0.6	-1.3	1.9	2.2
500	-0.1	0.1	-1.4	-0.7	-2.4	500	-1.8	-1.1	0.5	1.7	1.2
Mean	0.3	-0.6	-1.9	-0.8	-0.6	Mean	-2.6	-0.7	-0.3	1.5	1.1
SURF						SURF					
-pmsl	0.2	0	-5.9	-0.9	-1.7	-pmsl	1	-4.9	-3.6	-3.3	-0.7
-temp	-5.6	-3.4	-4.2	-3.9	-5.9	-temp	-4.5	-3.6	-1.2	-1.4	-7.1
-wind	-3.9	-5.4	-6.4	-6.9	-7.2	-wind	2.6	-1.3	-4.5	-5.6	-6
Mean	-3.1	-2.9	-5.5	-3.9	-4.9	Mean	-0.3	-3.3	-3.1	-3.4	-4.6
Mean all	0.1	1.1	0.3	1.2	0.5	Mean all	-0.3	-1.8	-2.1	-1.6	-1

TABLE 2.2

in TABLE 2.3.

TABLE 2.2 shows the same scores as TABLE 2.1 but for the Tropics and S. Hemisphere.

Tropical height scores show a substantial worsening, particularly at 700hPa. This is partly a reflection of the change in surface pressure bias which has changed to a negative bias for the trial. It may also be due to a reduction in gravity wave drag noticed in the earlier tests and which is a deficiency of the trial package (see Technical Report 127). S. Hemispheric height scores are generally better in the trial although there is some variation between T+72 and T+120 which may be a sampling problem due to the much smaller number of observations. Nevertheless the improvements are between 1 and 3 %.

Tropical rms errors for temperature are generally smaller in the trial, in contrast to the height scores, and are particularly improved at T+120 by 2-3%. Temperature scores for S. Hemisphere are generally the same for trial and operational. Lower atmospheric rms vector wind errors are better for both regions with changes of 1 to 5%. The tropical errors have been reduced by the increased low level drag from the orographic roughness.Relative humidity scores are mostly better for the trial in the tropics and evenly divided between trial and operational for S. Hemisphere. Rms vector wind errors for 10m winds are substantially improved for both regions as, mostly, are surface temperature and surface pressure rms errors.

Overall there are again reductions in rms errors for most parameters although generally not so great as for area 2 and N Hemisphere, notwithstanding the poor tropical height errors noted above.

TABLE 2.3 summarises the overall performance of the trial based on the scores in TABLES 2.1, AND 2.2. It shows the number of scores for which the rms changed by greater than 1% to decide whether the trial or operational were better in each area. For changes less than 1% operational and trial were deemed equal. With 30 fields and 5 verification times there are 150 scores in total for each area. The clear advantage of the trial version is demonstrated with positive signals outweighing the negative signals for all areas, including the tropics where the heights were so much worse.

TABLE 2.3 : Summary of objective verification scores from TABLES 2.1, AND 2.2

Area	Trial better	equal	operational better
N Atlantic ("2")	89	42	19
N Hemisphere	88	45	7
Tropics	53	73	24
S Hemisphere	83	47	20

TABLES 2.4, AND 2.5. summarise the percentage changes in rms errors for verification against analyses. The results are broadly similar to those for verification against observations with large improvements in area 2 and N. Hemisphere in height, temperature and vector wind errors, particularly at T+120, with again many of the changes of 10% or more. The benefits of increased and reduced drag at lower and upper levels respectively is shown by the 850 and 100hPa wind scores (**TABLE 2.4**).

The tropical height rms errors again show as very much worse with degradations of up to ~20% at 700hPa. Temperatures in the tropics are generally better, though the improvement is slightly smaller than when measured against observations. Winds are generally improved in both the tropics and S.Hemisphere, but especially at 850hPa for the tropics as was shown by the verification against observations. The rms surface pressure is now slightly worse for the trial for the tropical region.

As for the assessment against sondes and synop reports the verification based on analyses shows a similar picture with large or very large improvements in many parameters and there are no major discrepancies between the verification methods.

TABLE 2.6 summarises the overall performance of the trial based on the scores in **TABLES 2.4, AND 2.6**. It shows the number of scores for which the rms changed by greater than 1% to decide whether the trial or operational were better in each area,with changes less than 1% deemed equal. With 29 fields and 3 verification times there are 87 scores in total for each area. The clear advantage of the trial version is demonstrated with positive signals outweighing the negative signals for all areas except the tropics where the heights were so much worse.

TABLE 2.6 : Summary of objective verification scores from **TABLES 2.4, AND 2.5**

Area	Trial better	equal	operational better
N Atlantic ("2")	44	17	26
N Hemisphere	57	25	5
Tropics	26	31	30
S Hemisphere	38	41	8

2.2 BIASES AND VERTICAL DISTRIBUTION OF ERRORS

PMSL

FIGURE 2.1 shows the bias and rms errors ,verified against observations, from T+0 to T+120 for mean sea-level pressure for N Atlantic and N Hemisphere. The improved rms has already been noted but the change to the bias is remarkable. Similar increases of the bias are also found for the verification against analyses (not shown). In the earlier tests (see Technical note

RMSE	%CHANGE	(TRIAL-OPERATIONAL)	PERIOD 31/10/94-14/11/94					
	T+24	T+72	T+120			T+24	T+72	T+120
VERIFICATI	AGAINST	ANALYSES						
AREA	2				N.HEM			
HEIGHT					HEIGHT			
850	-2.7	-0.9	-9.2		850	-12.2	-8.6	-7.4
700	0	1.6	-8.8		700	-7.4	-6	-6.2
500	2.8	3.2	-7.4		500	-2.7	-2.7	-4.3
300	0.4	2.1	-6.7		300	-1.6	-1	-2.6
250	0	2	-6.8		250	-1.1	-0.4	-2.5
200	-0.8	2	-6.8		200	-0.8	0	-2.5
100	-5.4	-2.3	-8.3		100	-6.3	-6.3	-5.6
50	-5.6	-4.4	-9		50	-7.2	-7.1	-5.9
Mean	-1.4	0.4	-7.9		Mean	-4.9	-4.0	-4.6
TEMP					TEMP			
850	3.3	2.7	-2.4		850	1.5	1.8	-2.8
700	-1.7	2.7	-2.8		700	-1.6	1.9	0
500	-1.8	4.4	-3.2		500	0	2.3	1
300	4.9	5.4	-2		300	1.5	0.8	-0.9
250	0.7	5.7	1.5		250	-1.4	-1.4	-2.1
200	-2.1	0.3	-5.1		200	-5.1	-5.7	-6.7
100	-6.4	-6.4	-8.6		100	-12.1	-11.7	-8.2
50	-3.8	-6.5	-10		50	-7.2	-8.9	-6.6
Mean	-0.9	1.0	-4.1		Mean	-3.1	-2.6	-3.3
WIND					WIND			
850	-3.9	-4.3	-7.6		850	-10.1	-7.5	-7.9
700	2	0.5	-7.8		700	-3	-3.5	-6
500	3.3	2.6	-5.9		500	0.5	-0.7	-4.3
400	1.8	2.4	-5.7		400	0.3	-0.4	-3.4
300	1	2.1	-5.5		300	-0.7	-0.1	-2.2
250	1.6	2.3	-6.1		250	-0.2	0.7	-2.2
200	0.1	1.6	-6.6		200	-1.4	0.6	-2.3
100	-12.1	-11.6	-12.9		100	-20.1	-16.7	-11.1
Mean	-0.8	-0.6	-7.3		Mean	-4.3	-3.5	-4.9
RELHUM					RELHUM			
950	-8.1	-3.2	-3.1		950	-4.3	-1.6	-0.6
850	1.4	0.4	0		850	0.7	-1.6	-1.7
700	1.7	1.2	-0.9		700	0.2	0.6	0.3
500	-0.1	0.5	-1.5		500	-0.8	-0.4	-1.3
Mean	-1.3	-0.3	-1.4		Mean	-1.1	-0.8	-0.8
PMSL	-1	-0.9	-7.6		PMSL	-11.1	-6.9	-6.1

TABLE 2.4

RMSE	%CHANGE	(TRIAL-OPERATIONAL) PERIOD 31/10/94-14/11/94					
	T+24	T+72	T+120		T+24	T+72	T+120
VERIFICATI	AGAINST	ANALYSES					
TROPICS				S.HEM			
HEIGHT				HEIGHT			
850	4.6	7.2	9	850	-4.1	-5.5	-2.8
700	12.7	21.9	21.9	700	-2.8	-5.2	-2.9
500	17.5	20.9	20	500	-1.2	-3.5	-1.8
300	15.5	14.1	11.6	300	-0.9	-1.7	-0.7
250	16.5	15.2	12	250	-0.6	-1.3	-0.6
200	15.6	15.6	12.9	200	0.3	-1.2	-0.6
100	9.8	9.6	8.9	100	0.7	-1.4	-2.9
50	3	3.8	3.1	50	-0.3	-1.4	-4.3
Mean	11.9	13.5	12.4	Mean	-1.1	-2.7	-2.1
TEMP				TEMP			
850	1.2	1.4	-0.6	850	0	0.7	0
700	0	2.1	3.9	700	-0.7	1	1.1
500	0	0	-0.7	500	-0.7	-0.7	0.8
300	0	-1.5	-3.1	300	-0.7	0.4	0.6
250	0	-1.3	-2.2	250	0	-0.3	0
200	-1.1	-0.6	-0.9	200	-1.3	-1.3	-1.2
100	-2.9	-1.8	-2.2	100	-0.9	-2.5	-2.7
50	-1.4	-2.1	-4.1	50	0	-4.6	-5.6
Mean	-0.5	-0.5	-1.2	Mean	-0.5	-0.9	-0.9
WIND	RMSVW			WIND			
850	-5.9	-6.3	-5.4	850	-5.1	-3.5	-1
700	-1.5	-2.1	-1.5	700	-2.7	-2.6	-1.3
500	-1.2	-0.5	-0.4	500	-0.7	-0.6	-0.2
400	-0.6	-0.1	-0.8	400	-0.9	-0.3	0.3
300	0.3	-0.1	-1.6	300	-1.1	0.4	0.8
250	0.1	-0.2	-1.5	250	-1.1	0.3	1
200	-0.2	-0.7	-2	200	-1.5	0	1.1
100	-0.8	-1.5	-2.8	100	-2.4	-1.8	-1.8
Mean	-1.2	-1.4	-2.0	Mean	-1.9	-1.0	-0.1
RELHUM				RELHUM			
950	-4.3	-5.4	-5.4	950	-1.6	-0.9	2.4
850	-0.3	-0.8	-0.6	850	-0.3	-0.5	-0.4
700	-0.3	-0.3	0.9	700	1.1	2.4	2.2
500	1.3	0.6	-0.1	500	1	1.3	2
Mean	-0.9	-1.5	-1.3	Mean	0.1	0.6	1.6
PMSL	0	-0.6	1.4	PMSL	-5.2	-5	-2.4

TABLE 2.5

127) for December and January the operational version was too cyclonic with a negative surface pressure bias which was reduced by the trial package and in some cases replaced by a smaller positive bias. There is a seasonal variation of the bias. It appears that the effects of the increased low level and surface drag are too strong for the current trial period.

In the tropics, **FIGURE 2.2**, there is a reduction in mean pressure and a positive bias operationally has been replaced by a greater negative error. This is partly responsible for the very much worse rms height errors. In the S Hemisphere there is a beneficial slight reduction in positive bias.

FIGURE 2.3 shows scatter plots of rms errors in pmsl for the trial against operational versions from the 15 individual cases (31/10/94 - 14/11/94). In area 2 at T+72 the trial is better in 7 cases with 5 equal or nearly equal to the operational version. By T+120 the trial is better in 12 out of 15. For the N Hemisphere the trial and operational scores are more evenly split at T+72, although the 8 cases in which the trial is better are generally further from the diagonal than the operational cases which are better. By T+120 the trial is better in 10 out of 15. This shows that the trial is better more often on a daily basis and that the mean verification scores are not dominated by one or two exceptional cases.

HEIGHT

FIGURE 2.4 shows the bias (left) and rms (right) height error profiles for T+72 for area 2 (top) and N Hemisphere (bottom). **FIGURE 2.5** is the same but T+120. The operational negative bias has been much reduced so that now there is a positive bias below 500hPa. The magnitude of the changes in bias, which are approximately constant with height below 300hPa are consistent with the increase in surface pressure bias (**FIGURE 2.1**). The reduction in rms errors at T+72 is larger by T+120, as already noted in **TABLE 2.1**.

FIGURES 2.6 AND 2.7 are the same as **2.4 and 2.5** but for the tropics and S Hemisphere. The larger negative bias of the trial compared to the operational is again approximately constant for levels below 300hPa and explained by the larger negative bias of the surface pressure. Whilst this is probably responsible for an appreciable part of the increases in rms errors in the tropics, the changes in bias and rms are generally small for the S Hemisphere.

Similar changes in bias are found from the verification against analyses (not shown).

FIGURE 2.8 shows scatter plots or rms errors of 500hPa height. At T+72 more cases favour the operational version in area 2 and N Hemisphere, although the trial cases which are better show a larger improvement. By T+120, the trial is clearly better for 12 and 10 cases out of 15 for area 2 and N Hemisphere respectively. At higher levels the assessment is rather more clearly in favour of the trial, even at T+72, as shown by the scatter plots at 250hPa (**FIGURE 2.9**).

TEMPERATURE

FIGURE 2.10 shows the bias (left) and rms (right) temperature error profiles for T+72 for area 2 (top) and N Hemisphere (bottom). **FIGURE 2.11** is the same but T+120. The trial has

reduced the cold bias below 500hPa but has increased it around 300hPa by ~1/4 degree (T+72), ~1/2 degree (T+120). Rms scores are better at all levels except 300hPa. Verification against analyses shows a similar pattern of changes (**FIGURE 2.12**). However the warming is now confined to 850hPa only and the rms errors at T+72 are slightly worse up to 200hPa. This implies that the lower atmospheric warming is largely restricted to land, since the distribution of sondes is mostly over land. The cooling at upper levels is consistent with reduced gravity wave drag in the lower stratosphere and increased equator to pole temperature gradient to maintain thermal wind balance (see Technical Report 127).

Tropical temperatures are mostly warmed above 500hPa by ~0.2 K at T+120, again strengthening the equator to pole gradient (**FIGURE 2.13**), with cooling in the southern hemisphere from 500 to 200hPa. Tropical rms scores are better for the trial with a mixed response in the S Hemisphere.

WINDS

The overall effect of the trial package is for reduced wind speeds but generally better rms vector wind errors. The analysed winds (**FIGURE 2.14**) show increased negative bias from 850hPa which is largest to 300hPa (smallest) in area 2 and N Hemisphere. The underanalysis of wind strength operationally is believed to be due, at least in part, to the assimilation of layer averaged winds. The evidence here seems to suggest that the observations are being fitted even less well in the trial.

The T+24 forecast winds (**FIGURE 2.15**) from the trial show greater underforecast strength up to 250hPa, but the vector wind errors are mostly comparable to the operational with a slight improvement around jet levels. The difference in behaviour of the wind speed and vector wind errors suggests the trial version is forecasting direction more accurately for which there appears to be some evidence from the bias and rms directional errors (**FIGURE 2.16**) . Operationally the winds are scaled before dissemination. The verification has been performed using unscaled winds for both trial and operational. Given the change in wind bias the scaling factor will need to be reconsidered since the forecast wind strength, as a percentage of observed, now varies appreciably with height in the trial version (**FIGURE 2.17**).

FIGURE 2.18 shows the T+24 scores for the tropics, where the increased surface roughness has resulted in a mean negative bias at 850hPa, whereas at 300 and 400hPa the bias has been reduced. In the S hemisphere the speed bias is generally worse for the trial. Mostly the rms errors are better for the trial or the same in both areas.

The reduction in wind strength is greatest over land as expected so that verification against analyses (**FIGURE 2.19**) shows smaller changes generally, especially for the larger N Hemisphere area (cf **FIGURE 2.15**). There is a tendency for wind strengths to increase through the forecast operationally which the trial version removes so that at T+120 the trial biases are generally closer to zero outside the tropics (eg .**FIGURE 2.20**, N Hem).

The surface wind biases are made 2 to 3 knots lighter in the extratropics and ~1.5 knots

lighter in the tropics (**FIGURE 2.21,** left). The operational model is closer to zero bias. However the surface winds are generally too strong over land especially during winter (see eg Hammon and Wilson, 1994) so that this period of the trial is rather atypical. Surface wind speeds over the sea are reduced less , typically 1-2 knots in the extratropics and ~0.5 knots lighter in the tropics, when compared to "sea" stations. (NB many of the stations classed as "sea" by the verification scheme are actually land coastal stations or island stations and may not be representative of conditions over the open ocean.) Reduced lowest level winds will affect the global wave model which are driven by them. The instantaneous values of 10m wind speeds meaned over all ocean basins are within 1% of the operational. For the time meaned wind speeds during the period of the verification, the trial speeds are ~1% lighter than operational at T+0 and ~3% lighter by T+120. These would not cause concern with the wave model (Holt, personal communication).

SURFACE TEMPERATURE

FIGURE 2.22(left) shows the surface temperature biases to be much reduced by ~0.6-1.0 degree outside the tropics and by ~0.25 degree over the tropical region. Locally the changes can be much larger (see section 3).

RELATIVE HUMIDITY

FIGURE 2.23 shows the relative humidity biases and rms scores for area 2 and N Hemisphere. The largest changes in bias are found at 950hPa where the trial is beneficially drier due to the warming. At 850hPa the trial has a worse moist bias. The lowest level change has beneficial impact on cloud and precipitation (see sections 4 and 5, where the LAM precipitation verification shows the incidence of spurious light rain has been reduced).

2. 3 SUMMARY

The overall objective assessment shows the trial to have several beneficial impacts and particularly at T+120 a large reduction in error scores. The points of concern are the changes in surface pressure bias, the large resultant changes in height errors in the tropics and the reduction in wind strengths. The change to the nature of the biases for low level temperatures and surface temperatures will also effect the MOS forecasting of surface temperatures significantly.

3. SUBJECTIVE ASSESSMENT - GLOBAL MODEL

PARALLEL SUITE TRIAL DT12Z 25/10/94 - DT12Z 14/11/94

3. 1 NORTHERN HEMISPHERE

Analysis

Due to the coverage of observations, there was little difference between trial and operational analyses of mean sea level pressure and 500hPa in the Northern Hemisphere. However, there was a significant impact on low level wind speeds over land, with the trial

winds being reduced. The biggest impact was seen over high ground eg the Rockies, Himalayas and Greenland. Figure 3.1 shows the mean analysed 850hPa wind vector differences over the period 12Z 27/10/94 - 12Z 09/11/94 over Canada and Greenland (Figure 3.1a) and over Asia (Figure 3.1b). The easterly wind vector differences over the Rockies and Himalayas indicate a significant reduction in the wind speeds over land.

T+24 Forecasts

Comparing the trial and operational forecasts, it soon became apparent that the new gravity wave drag and orographic roughness was having a significant impact in the Northern Hemisphere. The low level winds were lighter due to the increased drag at low levels and with a warmer, drier boundary layer, low cloud was also reduced. Another signal at T+24 was a small rise in mean sea level pressure and contour heights over land north of 50N, with the biggest impact over Canada, east of the Rockies, and over northeast China and eastern Russia in the Vladivostok area. This resulted in a slight filling of depressions and 500hPa lows by the trial forecasts. Over Europe and the Atlantic, trial depressions were generally 1-3 hPa less deep than their operational counterparts and this was correct. However, some Canadian depressions in the area 52-65N, 80-110W were filled by 6-9hPa which was overdone. Similarly, some depressions over eastern Russia and Japan, 50-60N 130-160E were also filled too quickly.

An example of the occasional overfilling of depressions over Canada at T+24 is provided by Figure 3.2. This figure compares the trial (a) and operational (b) mean sea level pressure forecasts for T+24 over Canada with the verifying analysis (c). The operational forecast predicted the depth of the depression near Hudson Bay to be 977hPa which agreed well with the analysis. The trial predicted a depth of 983hPa, which was 8hPa too high.

Similarly, the trial filled the 500hPa low over Hudson Bay too quickly. The trial and operational T+24 forecasts for 500hPa over Canada are compared in Figures 3.3a and 3.3b respectively. The trial forecast of 517dm for the depth of the low was 5dm higher than the operational forecast. The verifying analysis (Figure 3.3a) again agreed with the operational forecast.

Jet maxima at 250hPa tended to be slightly weaker overland in the trial forecasts at T+24. In a comparison of 30 trial and operational jets which differed by at least 3 ms^{-1}, the trial jets were weaker in 23 cases by 3-8ms^{-1}. However, 19 out of the 30 verified better against the analysis. The trial and operational 250hPa winds over the Atlantic for T+24 are compared in Figure 3.4. The forecast wind speeds were meaned over the period 12Z 28/10/94 to 12Z 10/11/94 for both forecasts. The comparison shows very little difference in the strength of the 250hPa winds across the Atlantic. However, when we compare the trial and operational mean 250hpa jet speeds over America for T+24, (Figures 3.5a/b respectively), then the trial jets were slightly weaker.

T+72 forecasts.

The problems with the operational model led to many depressions and cold pools being

too deep. The impact of the new gravity wave drag and orographic roughness could be seen clearly at T+72, with most trial depressions and cold pools being less deep and generally higher values of mean sea level pressure and 500hPa contours. Most jet maxima at 250hPa were weaker, reducing the westerly bias of the model. A few evolution changes resulted in the opposite effect but generally the impact of the trial was as described above. In most cases the trial changes were beneficial with the higher mean sea level pressure and 500hPa heights verifying better. However, there were one or two worrying cases in which the impact of the trial changes were overdone with depressions and cold pools being filled too quickly, resulting in errors in evolution.

Figure 3.6 c shows the differences at T+72 between the trial and operational mean sea level pressure forecasts, meaned over the period 12Z 30th October to 12Z 15th November. The chart indicates a general rise in pressure over land north of 45N at T+72, with the maximum impact (+10hPa) downwind of the Himalayas over eastern Russia and the Sea of Okhotsk, 50-60N 140-150E. During the trial, there was a succession of depressions moving out from eastern Russia northeastwards towards the Bering Sea. There were some very big differences between trial and operational depressions in this region, with the operational forecasts overdeepening and the trial forecasts filling. Figure 3.6a shows the operational mean sea level pressure errors at T+72 against the analysis, meaned over the same period. The chart shows that the operational forecasts had a large negative bias of -8hPa over Western Canada and also over the Sea of Okhotsk/Bering Sea. Figure 3.6b shows the trial errors at T+72 for comparison. The large negative bias over the Sea of Okhotsk/Bering Sea in the operational forecast has been switched to a smaller positive bias of 4-6hPa in the trial forecasts and the negative bias over Western Canada has been reduced from -8hPa to -4hPa. The trial forecasts show a mainly positive bias over land, especially over eastern Canada (Hudson Bay).

The analyses shown in Figures 3.7 a and b indicate the position and depth of a very deep depression, 968mb, over eastern Russia/ Sea of Okhotsk at 12Z 7/11/94. Associated with this depression, there was a deep 500hpa low, 497dm. The trial and operational T+72 forecasts for the depth of this depression differed by 35hPa! The operational forecast, Figure 3.8b, predicted the position of the depression accurately but overdeepened it by about 20hPa (ECMWF similarly). The trial depression, 978hPa, was closer to the analysed value but the position was too far southeast. Similarly, the 500hPa low forecast by the operational model ,(Figure 3.9b) ,was well positioned but too deep, whilst that predicted by the trial forecast,(Figure 3.9a),was too far south and not deep enough.

T+120 forecasts.

The comparison between T+120 forecasts was dominated by changes in evolution. Where the comparison was still valid, this meant that occasionally trial depressions could be deeper and jets stronger. This was particularly the case with the jets where nearly as many jets were stronger as weaker, but the majority of trial depressions and 500hPa lows were still less deep. Generally the subjective assessment favoured the trial but with the same reservations expressed above. The following two examples illustrate the large differences

seen at T+120.

The first case is a second example of the big differences seen in the prediction of depressions in the active storm track region between Japan and the Bering sea at T+120. The mean sea level pressure and 500hPa analyses for 12Z 12/11/94, Figures 3.10 a/b respectively, show a deep depression, centre 989hpa, in the Sea of Okhotsk, and corresponding 500hPa trough, 510dm. The position of the depression, if not the depth, was confirmed by observations. The trial forecast for T+120, shown in Figure 3.11a, predicted the depression too far south and not nearly deep enough. The operational forecast for T+120 , Figure 3.11b, predicted a more accurate depth and track of the depression. A comparison of the 500hPa troughs for T+120, Figures 3.12a/b respectively, show that the trial trough was held back too far over land and was not deep enough.

The second case illustrates a difference between the trial and operational forecasts over the North Atlantic at T+120. The mean sea level pressure analysis for 12Z 5/11/94, Figure 3.13a, features a deep depression, 978hPa, centred close to Greenland with a trough extending southeastwards to a smaller low centred at 50N 25W. The 500hpa analysis for the same time, Figure 3.13b, features a trough extending from Greenland southeastwards. The trial mean sea level forecast for T+120, verifying at 12Z 5/11/94, shown in Figure 3.14a, predicted the position and depth of the Greenland depression very accurately, although the trough to the southeast was too far west. However, there was a large forecast pressure error over Ireland and the U.K. with a strong ridge of high pressure predicted incorrectly. The corresponding operational T+120 forecast is shown for comparison in Figure 3.14b. The forecast over the Central Atlantic was much less accurate with the Greenland depression being predicted 15 degrees too far east. The operational forecast also built a ridge of high pressure across the south of the U.K. incorrectly. Similar comments apply to the trial and operational 500hPa forecasts for T+120, compared in Figures 3.15a,b respectively. Neither forecast predicted the extension of the 500hPa trough from Ireland to Spain correctly.

A comparison of the trial and operational T+120 250hPa wind forecasts for the North Atlantic, Figures 3.16 a/b respectively, show that the operational forecast was more zonal, with the Newfoundland jet extending further eastwards across the Atlantic. The trial forecast compares better with the verifying analysis, Figure 3.16c, in the central Atlantic but both forecasts have predicted the 250hPa trough too far east over the U.K..

3.2 Southern Hemisphere

Differences over the Southern Hemisphere were less and forecast evolution changes less marked. There were analysis differences over Antarctica but these did not grow to cause forecast differences. The subjective assessment slightly favoured the trial forecasts. One example is given to illustrate the largest difference seen in the South Atlantic around South America.

The storm track in the South Atlantic was close to the Falkland Islands and Tierra del Fuego. The mean sea level pressure analysis for 12Z 06/11/94 for the South Atlantic, Figure 3.17a, shows a series of depressions moving just to the south of the Falklands and Cape Horn. The trial and operational forecasts for T+72, compared in Figures 3.18a and 3.18b respectively, are very similar in evolution and the main difference is in the forecast depth of the depression at 45S 40-45W. Both forecasts have overdeepened this low with the trial forecast closer to the analysis (analysis 989hPa, trial 978hPa, oper 969hPa) .

Figure 3.19c shows the differences at T+72 between the trial and operational mean sea level pressure forecasts, meaned over the period 12Z 30th October to 12Z 15th November. The differences are much smaller than those seen in the Northern Hemisphere and the main feature is a positive difference, 2-4hPa, in the storm track south of the Falklands Islands. The operational T+72 mean sea level pressure errors against the operational analysis for this period, Figure 3.19a, indicate a negative bias, -4 to -8hPa, south of the Falklands. This negative bias has been reduced to -2 to -4hPa in the trial forecasts, as shown in Figure 3.19b.

During the parallel suite trial, one case did appear to be slightly more noisy at T+120 than the operational forecast over Antarctica. Other investigations in the use of longer physics timesteps and tracer advection schemes have revealed a tendency for more noise to be generated in some situations by the orographic roughness/gravity wave drag changes. In the present set-up this is controlled by both the horizontal diffusion and if necessary a shorter dynamics timestep but at present it is not a serious problem.

3.3 CONCLUSIONS-SUBJECTIVE ASSESSMENT

1. Higher values of mean sea level pressure and 500hPa heights in the trial forecasts mainly verified better.

2. Forecasters need to be informed of a marked reduction in low level wind speeds over land.

3. Warmer boundary layer with reduced low cloud (10% reduction).

4. Reduced westerly bias later in forecast.

5. Depressions and 500hPa lows generally less deep.

6. Above effect sometimes overdone downwind of Rockies and Himalayas early in forecast.

4. OBJECTIVE VERIFICATION - LIMITED AREA MODEL

The analyses and forecasts were verified against observations (Sondes and synops) for the period 31/10/94 to 14/11/94 as for the global model. Verification was also performed against analyses, each suite was verified against its own analyses for the same period. Time-

mean results will mostly be discussed here . Results for forecast times T+0, T+24 and for areas "5", "88" and for analyses "888" will be given. The areas are shown in **FIGURE 4.1**; note "888" is the full LAM area.

4. 1 RMS ERRORS -OVERALL SUMMARY

Only a brief summary of the main results will be given since most of the major impacts have already been described for the global model in section 2.

TABLE 4.1 summarises the objective scores for verification against observations. It shows the percentage changes in rms errors for heights, temperatures and winds (6 levels each) and relative humidity (3 levels) and 3 surface fields. A negative value shows the trial to be an improvement. Column and surface-means are also shown.

The major reductions in height, temperature and wind rms errors are at 850hPa. T+24 forecast winds at and above 200hPA are greatly reduced also. The 500hPa height error for the larger area (88) is worse in the trial, which agrees with the results for area 2 in the global verification. Temperature changes are generally less beneficial for the trial and at 250hPa there is a worsening of the rms errors particularly for the smaller region "5". For the larger region "88" nearly all the surface errors are reduced by appreciable amounts. However the T+24 surface temperatures for area "5" are significantly worse.

TABLE 4.2 summarises the overall performance of the trial based on the scores in **TABLE 4.1**. It shows the number of scores for which the rms changed by greater than 1% to decide whether the trial or operational were better in each area. For changes less than 1% operational and trial were deemed equal. With 24 fields and 2 verification times there are 48 possible scores in total for each area.

As with the global model this simple count shows the benefits of the trial outweighing the disadvantages.

TABLE 4.2 : Summary of objective verification scores from **TABLE 4.1**

Area	Trial better	equal	operational better
5	20	22	6
88	20	24	4

TABLE 4.3 summarises the objective scores for verification against analyses. The beneficial impacts of the trial are again seen at 850hPa for heights and winds and at 100hPa for winds. Surface pressure errors are also reduced. Generally however the scores are worse than the operational in distinction to the verification against sondes. The overall summary is shown in

%RMS	CHANGE	(TRIAL-OPERATIONAL) PERIOD 31/10/94-14/11/94				
VERIFICATI	AGAINST	OBSERVATIONS				
	T+0	T+24			T+0	T+24
AREA	5			AREA	88	
HEIGHTS				HEIGHTS		
850	0.3	-6.4		850	0.1	-5.2
500	-2.1	-2.3		500	-1.1	2.1
300	-2.7	-1.7		300	-2.4	-0.8
250	-0.5	-1.6		250	-0.7	-0.7
200	1.2	0.1		200	-2	-0.3
100	-0.7	2.5		100	-1.3	-0.5
Mean	-0.8	-1.6		Mean	-1.2	-0.9
TEMPERATURES				TEMPERATURES		
850	-0.1	-2.9		850	1.5	-0.2
500	1.4	-0.4		500	-0.7	-1.9
300	-0.5	1.5		300	1.4	-0.2
250	-3.6	4		250	-0.6	1.7
200	-0.5	0		200	-0.4	0.7
100	0	-0.1		100	0	0.5
Mean	-0.6	0.4		Mean	0.2	0.1
WINDS				WINDS		
850	0.5	-3.9		850	-0.3	-6.1
500	0.7	-0.4		500	0.4	0.8
300	-0.6	-0.9		300	-0.4	-1.3
250	1	0.8		250	-0.5	-0.5
200	-0.6	-5.1		200	-0.8	-1.1
100	-1.6	-6.3		100	-1.2	-4.2
Mean	-0.1	-2.6		Mean	-0.5	-2.1
RH				RH		
850	-1.8	-4.6		850	0.1	-3
700	-1.2	-2.7		700	-0.2	-1.9
500	-2.2	-1.7		500	-0.8	-1.2
AV1	-1.7	-3		Mean	-0.3	-2
SURFACE				SURFACE		
-pmsl	-0.5	0		-pmsl	-1.1	-6.8
-temp	0.7	6.5		-temp	-5.1	-3.1
-wind	-4.4	-5.6		-wind	-7.2	-10
Mean	-1.4	0.3		Mean	-4.5	-6.6
Mean all	-0.7	-1.3		Mean all	-1	-1.8

TABLE 4.1

RMSE	%CHANGE	(TRIAL-OPERATIONAL)	PERIOD 31/10/94-14/11/9		
VERIFICATION AGAINST ANALYSES					
	T+24		T+24		T+24
AREA	5	AREA	88	AREA	888
HEIGHT		HEIGHT		HEIGHT	
850	0.6	850	-3.4	850	-2.8
500	4.5	500	3.7	500	4.9
300	1.4	300	3.8	300	2.9
250	0.3	250	3.6	250	3.3
200	1.2	200	3.9	200	3.9
100	3.8	100	3.6	100	1
TEMP		TEMP		TEMP	
850	3.9	850	2.5	850	2.4
500	0	500	0.9	500	-0.9
300	4.1	300	2.1	300	2.1
250	3.9	250	1.9	250	1.9
200	0.6	200	0.7	200	-0.7
100	-2.6	100	-4.9	100	-9.3
WIND		WIND		WIND	
850	-2.7	850	-5.6	850	-6.5
500	2.7	500	2.6	500	1.6
300	1.7	300	2.5	300	1.1
250	0.8	250	1.4	250	-0.2
200	-1.1	200	0.5	200	-0.1
100	-3	100	-5.7	100	-12.9
RELHUM		RELHUM		RELHUM	
950	-1.6	950	-2.7	950	-3
850	-1.1	850	-1.8	850	-1.6
700	-0.9	700	0.4	700	0.2
500	-0.3	500	0.3	500	-0.1
PMSL	1	PMSL	-4	PMSL	-3.9

TABLE 4.2

TABLE 4.4. With 23 fields and 1 verification times there are 23 possible scores in total for each area. These results are rather inconsistent with those from both the verification against observations for the limited area model and both verification against observations and analyses for the global model (see section 2.1). The results here show the operational to be better overall.

TABLE 4.4 : Summary of objective verification scores from TABLE 4.3

Area	Trial better	equal	operational better
5	6	8	9
88	7	6	16
888	7	7	15

4.2 BIASES

FIGURE 4.2 (left) shows the increase in positive bias of surface pressure for areas 5 and 88 similar to that found with the global model for the north Atlantic (area 2).

FIGURE 4.3 shows the warmer surface temperatures and beneficial reduction in bias. However the T+24 rms errors for the smaller area are noticeably worse.

FIGURE 4.4 (left) shows the positive surface wind bias is replaced by a (slightly, for area 88) greater negative bias for the trial.

4. 3 LAM PRECIPITATION VERIFICATION

The operational and trial precipitation accumulations per 6 hour periods from T+0 to T+24 were verified against station observations. The results are presented in contingency tables for the following categories of accumulated precipitation - 0, <0.1mm, L, 0.1 < P <2mm, M 2.0< P <10mm and H, P > 10mm. (0=none, L=light, M=medium, H=heavy). The most noticeable impact on the scores was a reduction of the forecasting of light rain when none was observed. The results were consistent for all forecast periods and we will only present T+18-T+24 results here (TABLE 4.5) for the UK and whole LAM areas (land).

The bias (forecast rain events/ observed rain events) is lower for the trial and the % correct on a yes/no basis is improved by 2%. The hit rate is correspondingly reduced since there are now fewer spurious rain forecasts (NB a model which forecast precipitation at all points would score 1 for the hit rate since it only measures successful forecasts of precipitation!). The threat scores and Hanssen and Kuipper scores which take account of the false alarm rate show the trial to be better . The contingency tables show a reduction in the light forecast/ none observed category with a smaller increase in the none forecast/ light observed and more correctly predicted none observed/none forecast category. These are largely responsible for

OPERATIONAL

* WHOLE FINE MESH LAND AREA *					
+ FORECAST PERIOD= 18- 24 +					
+ + OBS + +					
+ + 0 L M H | +					
+F/C+ + +					
+ 0 + 60.3	3.1	0.5	0.1+	64.0+	
+ + + +					
+ L + 16.9	7.9	2.6	0.2+	27.6+	
+ + + +					
+ M + 1.8	3.1	2.1	0.7+	7.7+	
+ + + +					
+ H + 0.2	0.1	0.3	0.2+	0.8+	
+ + + +					
+ + 79.3	14.1	5.5	1.1+	100.0+	

BIAS= 1.7
THREAT SCORE(0.1)=43.0
HANS & KUIPER SCORE =0.58
% CORRECT ON YES/NO BASIS=77.4
CORRECT IN ALL CATEGORIES=70.5
HIT RATE =.824

TEST VERSION

* WHOLE FINE MESH LAND AREA *					
+ FORECAST PERIOD= 18- 24 +					
+ + OBS + +					
+ + 0 L M H | +					
+F/C+ + +					
+ 0 + 63.2	3.7	0.5	0.0+	67.3+	
+ + + +					
+ L + 13.8	7.7	2.5	0.3+	24.3+	
+ + + +					
+ M + 2.0	2.7	2.2	0.6+	7.5+	
+ + + +					
+ H + 0.2	0.1	0.3	0.3+	0.8+	
+ + + +					
+ + 79.3	14.1	5.5	1.1+	100.0+	

BIAS= 1.6
THREAT SCORE(0.1)=45.0
HANS & KUIPER SCORE =0.60
% CORRECT ON YES/NO BASIS=79.8
% CORRECT IN ALL CATEGORIES=73.4
HIT RATE =.800

OPERATIONAL

* WHOLE UK AREA *					
+ FORECAST PERIOD= 18- 24 +					
+ + OBS + +					
+ + 0 L M H | +					
+F/C+ + +					
+ 0 + 35.3	7.9	0.4	0.0+	43.5+	
+ + + +					
+ L + 20.8	14.2	5.4	0.2+	40.5+	
+ + + +					
+ M + 1.4	7.7	5.9	0.4+	15.4+	
+ + + +					
+ H + 0.4	0.2	0.0	0.0+	0.5+	
+ + + +					
+ + 57.9	29.9	11.6	0.5+	100.0+	

BIAS= 1.3
THREAT SCORE(0.1)=52.4
HANS & KUIPER SCORE =0.41
% CORRECT ON YES/NO BASIS=69.2
% CORRECT IN ALL CATEGORIES=55.4
HIT RATE =.804

TEST VERSION

* WHOLE UK AREA *					
+ FORECAST PERIOD= 18- 24 +					
+ + OBS + +					
+ + 0 L M H | +					
+F/C+ + +					
+ 0 + 40.1	9.9	0.7	0.0+	50.7+	
+ + + +					
+ L + 15.9	13.8	5.4	0.2+	35.3+	
+ + + +					
+ M + 1.6	6.3	5.2	0.4+	13.4+	
+ + + +					
+ H + 0.2	0.0	0.4	0.0+	0.5+	
+ + + +					
+ + 57.9	29.9	11.6	0.5+	100.0+	

BIAS= 1.2
THREAT SCORE(0.1)=52.7
HANS & KUIPER SCORE =0.44
% CORRECT ON YES/NO BASIS=71.7
% CORRECT IN ALL CATEGORIES=59.1
HIT RATE =.749

TABLE 4.5

the overall improvement of the threat and Hanssen and Kuipper scores.

4. 4 SUMMARY

The overall objective assessment of the LAM shows similar benefits and impacts to that found for the global model in the N Atlantic area. The verification against analyses however is a little out of line with the general trend of the results. The improvement in surface and lower atmospheric temperatures appears to have had a beneficial effect on removing spurious light precipitation.

5. SUBJECTIVE ASSESSMENT - LIMITED AREA MODEL

PARALLEL SUITE TRIAL DT00Z 27/10/94 - DT00Z 15/11/94

No changes in evolution were seen in the LAM trial forecasts but there was a noticeable impact upon mean sea level pressure, low level winds, precipitation and temperature.

a) Mean sea level pressure.

Mean sea level pressure was slightly higher in the trial forecasts and there was a slight filling of depressions, especially over land which was sometimes overdone. In most cases, the difference was small, 1-4hPa, but occasional differences of 5-10hPa were seen at T+24/36 over Canada. In a comparison of 22 depressions at T+36 which differed by 4hPa or more, the trial depressions were filled by 4 to 10hPa. Eleven of these were filled correctly but the other eleven were filled too much or too soon. The favoured area for over-filled depressions was over eastern Canada, within the area 55-65N,75-100W. Changes over Europe were usually beneficial. Over the eastern Atlantic and U.K. differences were small, 1-4hPa, with occasionally one isobar less in depressions.

Figure 5.1 a/b illustrates the kind of differences seen between operational and trial depressions over land at T+36. The forecast depths of 5 depressions over North America and Europe are listed below. The trial depressions are slightly less deep in all 5 cases.

depression	oper	trial	CFO anal	
51N 100W	997	1001	1000	hPa
60N 80W	994	997	994	hPa
52N 58W	979	985	981	hPa
64N 62E	984	990	986	hPa
42N 40E	1002	1006	1007	hPa

b) Low level winds.

The trial low level winds were noticeably lighter over land due to the increased drag at low levels . Figures 5.2 and 5.3 illustrate the differences between the forecast 10m winds from the operational and trial forecasts for 13th November. Comparing the two forecasts, it

is noticeable that the trial forecast wind speeds were lighter over land. Over the U.K. at 12z, for example, surface wind speeds of 20 knots in the operational forecast over the northwest Midlands,(Figure 5.2), were reduced to 10 knots in the trial forecast,(Figure 5.3), and surface winds of 15 knots in the operational forecast over southeast England were reduced to 10 knots in the trial forecast. Figure 5.4 shows the observed winds at 12Z 13th November. Over the northwest Midlands and northwest England, in areas sheltered by the Welsh mountains, reported wind speeds varied from 10-15 knots, rather between the operational and trial forecasts. Over southeast England, observed wind speeds of mainly 10-15 knots verified slightly better for the operational forecast. The contrast between trial and operational wind speeds was even more marked in the T+24 forecast verifying at 00Z 14th November. Over northwest England, the operational forecast of 25-30 knots was reduced to 10 knots in the trial forecast. With the wind coming from a south to southwesterly direction, northwest England was well sheltered by the Welsh mountains and observed wind speeds were only 10 knots at midnight (see observations for 00Z 14th November in Figure 5.5). Over the East Midlands and East Anglia observed wind speeds at 00Z were 15-20 knots generally, compared to forecasts of 20-25 knots by the operational forecast and 10-15 knots from the trial forecast.

This case gives a good example of the differences between the trial and operational 10m winds. Lighter winds overnight and in areas sheltered by high ground were better predicted by the trial forecasts. However, strong winds over exposed areas were slightly under-forecast by the trial and slightly over-forecast by the operational model.

c) Temperatures and low cloud.

Lighter low level winds led to less mixing in the boundary layer and as a result there was a reduction in low cloud. This was most noticeable inland and occasionally over the sea in westerly airstreams. 1.5m temperatures were slightly higher at 12Z.

The operational and trial forecast precipitation rates and 6-hour accumulation charts for T+12, verifying at 12Z 10th November can be compared in Figure 5.6, with the operational charts on the left. Comparing these charts, especially the accumulation charts, it is interesting to note that the trial forecasts predicted less light precipitation generally, notably over the sea west of Ireland, the North Sea and also over the West Midlands and Germany. This was a fairly consistent feature of the rainfall forecasts during the trial. The largest error in the operational rainfall verification is the amount of spurious light rainfall predicted by the model and any reduction would be beneficial.

A comparison of the operational and trial cloud forecasts in Figures 5.7 a/b respectively indicates that the reduction in light precipitation in the trial forecast was related to the decrease in the amount of low cloud forecast. The trial forecast predicted much less low cloud over the sea west of Ireland and also over Ireland. The meteosat visual satellite image for 12Z 10th November, Figure 5.8, shows the presence of low cloud over Ireland but good breaks in the cloud over the Atlantic west of Ireland. This case suggests that the low cloud and light precipitation was over predicted in the operational forecast but slightly under

predicted in the trial forecast.

The reason for the reduction of low cloud in the trial forecast can be seen by comparing the operational and trial 1.5m temperature forecasts in Figures 5.7 c/d respectively. The trial forecast is 2 degrees warmer over Ireland and over the sea just to the west. The reduction of low cloud and light precipitation is due to a warmer and drier boundary layer. The observations for 12Z 10th November ,Figure 5.9, confirm the presence of low cloud over Ireland but the temperatures were mainly 10-11 degrees Celsius, which agrees better with the trial forecast.

d) 250hPa jets.

A comparison of 250hPa jet maxima showed that the trial jets were slightly weaker due to a reduction in the westerly component. This reduction was mainly less than 5 knots. In a study of 22 jets which differed by more than 5 knots, the trial jets were weaker in 20 of these, with the verification slightly in favour of the operational jets. The five jets which differed by more than 10 knots were over North America in the region 48N 90-100W. Two of these verified in favour of the trial jets and two in favour of the operational.

e) Precipitation

Frontal rain bands were similar, although there were occasional differences in intensity and accumulations. Trial rain bands were slightly narrower due to a reduction in the very light rain on the edges. The most noticeable difference was the reduction in the large amounts of very light rain (much of it spurious) predicted by the operational model. This resulted from the reduction in low cloud. There was a slight enhancement over windward coasts, with more clearances inland.

The frontiers radar image in Figure 5.10a for 12Z 30th October shows a large area of rain over southwest England, South Wales and the Channel with predominantly dry weather over most of southeast England, East Midlands and East Anglia. The T+12 operational rainfall forecast for this time, Figure 5.10b, has predicted too much very light rain and drizzle over England and Wales ahead of the main rain area. The trial T+12 forecast, Figure 5.10c, predicted the dry areas better.

The next example shows a difference in the model output. The radar image, Figure 5.11a, indicates an active frontal system over western Scotland, Wales and southwest England at 18Z 3rd November.. There was a difference between the operational and trial rainfall forecasts at T+18 over Wales and southwest England, with the operational, Figure 5.11b, predicting showers and the trial, Figure 5.11c, predicting mainly dynamic rain. The radar image indicated that the rain was occasionally heavy over South Wales and southwest England but we could not find any reports of thunderstorms. Both forecasts could be justified: there may be a slight preference for the dynamic rainfall band in the trial forecast, allowing for the slight positional error, but the operational forecast predicted the rain/showers ahead of the main trough better.

The final example shows a difference in the forecast distribution of showers over England in an unstable westerly airstream around a depression over Scotland. The frontiers radar image for 12Z 31st October, Figure 5.12a, shows the main area of rain associated with a cold front just clearing southeast England, with showers in the west. Eastern England, just west of the cold front was mostly dry. The operational forecast at T+12, Figure 5.12b, predicted showers across Wales and the Midlands, extending too far east into the East Midlands. The trial T+18 forecast, Figure 5.12c, confined the showers to Wales and West Midlands with slightly larger accumulations, which was better. The slight enhancement of showers in the trial forecast was probably due to increased convergence on the coast due to the lighter winds inland.

5.1 CONCLUSIONS- SUBJECTIVE ASSESSMENT

1. Mean sea level pressure was slightly higher in the trial forecasts and there was a slight filling of depressions, especially over land which was sometimes overdone over Canada.

2. 10M winds were noticeably lighter over land. Lighter winds overnight and in areas sheltered by high ground were better predicted by the trial forecasts. Strong winds over exposed areas were slightly under-forecast by the trial and slightly over-forecast by the operational model.

3. Lighter low level winds led to less mixing in the boundary layer and as a result there was a slight increase in temperature and reduction in low cloud.

4. Trial 250hPa jet maxima were slightly weaker due to a reduction in the westerly component.

5. Trial rain bands were slightly narrower due to a reduction in the very light rain on the edges. The most noticeable difference was the reduction in the large amounts of very light rain (much of it spurious) predicted by the operational model.

6 FINAL REMARKS

The parallel suite trial has shown most of the expected benefits from including a new parametrisation of surface roughness due to sub grid scale orography and to a revision of the gravity wave drag scheme. These were found in the earlier tests for N Hemisphere winter (see Technical Report 127). The parallel suite suffers from not being run at the most appropriate time of year and so the overall assessment should be made in conjunction with those tests.

There are several areas where the schemes can be improved:

1) The specification of the surface parameters for the orographic roughness have been parametrised from the standard deviation of the orography. They should ideally be determined from very high resolution data. Such data is available for most of Europe and a re-evaluation of the parametrisation is now under way. When available the model should be run with the better specification of surface roughness.

2) Little is known about the drag due to very high roughness in steep mountainous areas and the scheme could require further tuning.

3) The gravity wave drag scheme has a number of assumptions concerning the calculation of "surface stress" such as the appropriate wind level and the vertical distribution of drag. These also could be subject to further revisions.

Given the above reservations it is clear that the present package is unlikely to be optimally tuned and is not yet recommended for operational implementation. A second trial is proposed with revised specification of the surface roughness ancillary parameter A/S (= total silhouette area of unresolved orography) and a better treatment of scalar transport by the orography roughness scheme. The impact of lighter surface winds on the global wave model can also be assessed directly by forcing the model with winds from the parallel suite.

If implemented operationally the behaviour of the global and limited area models should then be closely monitored and further revisions made as appropriate.

8 ACKNOWLEDGEMENTS

The new gravity wave drag scheme was first proposed by Glen Shutts (APR division) and has been coded and developed for the Unified Model by David Gregory and James Mitchell (Climate Research division). The orographic roughness scheme has been developed for the Unified Model by Simon Jackson and Roderick Smith, with ancillary field parameters derived by Clive Jones and Ruth Evans (all FR division). The corrections to eliminate the superadiabatic profiles were developed by Roderick Smith.

REFERENCES

Hammon O and C A Wilson, 1994:
Increased surface roughness in the Limited Area Model. *FR Technical Report* ***95***

Milton S F, C A Wilson,R A Stratton,O Hammon and F Rawlins, 1994:
Impact of anew gravity wave drag scheme and orographic roughness in the Unified Model. I Global model tests. *FR Technical Report* ***127***

C A Wilson, F Rawlins and O Hammon, 1994:
Cause and cure of the superadiabatic lapse rate in the limited area and global models. *FR Technical Report* ***125***

APPENDIX- EXTENDED TRIAL OBJECTIVE VERIFICATION

The trial was continued from 15/11/94 to 23/11/94 with an addition set of corrections for the elimination of superadiabatic profiles **(see Technical Report 125** (Wilson et al, 1994)). These corrections had a generally very small or neutral impact on the verification; this was also found here for the period 15/11/94 to 23/11/94. Rather than show these results, summary tables of the verification for the whole period 31/10/94-23/10/94 are presented which confirm the findings of section 2 but for a larger sample of cases. Only rms errors are discussed.

TABLE A.1 summarises the objective scores of verification against observations (sondes and synops) for the N. Atlantic region (area 2) and extratropical N. Hemisphere, and may be compared to **TABLE 2.1**. A similar overall picture is found as for the earlier period. However over the N Atlantic region the impact at T+120 is reduced eg ~5% improvement in heights rather than ~10%, temperatures and winds ~3% and 7% rather than 6 and 10%. The improvements at T+48 and T+72 are however slightly larger. For the N. Hemisphere at T+120 the impact is very similar as for the earlier period, but again the impact is slightly greater at T+48 and T+72. Thus, although the details are affected by synoptic variability over the trial period, particularly for the smaller region, the general trend of improved scores, particularly at later forecast ranges, is confirmed.

TABLE A.2 summarises the objective scores of verification against observations (sondes and synops) for the Tropics and extratropical S. Hemisphere, and may be compared to **TABLE 2.2** Again the results of the earlier period are largely confirmed with the poorer tropical height errors standing out. The tropical wind improvements at lower levels are greater, ~7% rather than ~5%, but the 100hPa improvement is smaller. In the S. Hemisphere the discrepancy between the impact at T+72 and T+120 for the height errors is less than was found for the earlier period and winds are generally improved by a larger percentage.

For completeness **TABLES A.3 AND A.4** show the percentage improvements in rms errors from the verification against analyses over the whole period and may be compared to **TABLES 2.4 AND 2.5**. The reduced impact at T+120 is again found for area 2. N. Hemispheric errors at T+24 and T+72 are reduced by more, as was found for verification against observations. Similarly, the greater improvement in tropical winds at lower levels and smaller improvement at 100hPa, and the more consistent height improvements in the S. Hemisphere for T+72 and T+120 are all evident and confirm the conclusions from the verification against observations.

Overall the conclusion reached from the earlier period that, the trial version has many more positive benefits than disadvantages, is valid for the results from the whole parallel suite period.

%RMS CHANGE (TRIAL-OPERATIONAL), PERIOD 31/10/94-23/11/94											
VERIFICATION AGAINST OBSERVATIONS											
	T+0	T+24	T+48	T+72	T+120		T+0	T+24	T+48	T+72	T+120
AREA	2					AREA	200,N Hem to 30N				
HEIGHTS						HEIGHTS					
850	1.4	1.9	-3.2	-4.9	-2.6	850	1.3	-2.8	-6.8	-5.9	-4.4
700	1.9	3.3	-1.3	-3.2	-3.9	700	2.3	2.6	-2.9	-4	-4.3
500	0.7	0.4	1.4	-1.9	-4.9	500	0.6	3.5	-1.1	-2.9	-4.4
300	-0.5	-5.1	-2.6	-3.5	-4.4	300	-0.2	-0.4	-1.9	-3.7	-3.7
250	-0.2	-4.5	-1.9	-3.3	-4.1	250	0	-0.2	-1.1	-3.1	-3.4
200	-0.4	-3.3	-1.6	-2.6	-4.1	200	-0.3	0.4	-1	-2.7	-3.8
100	-0.1	-3.8	-5.5	-6.2	-8.9	100	-0.6	-1.1	-5.7	-7.3	-8.9
50	-0.6	-2.9	-5.2	-7	-9.4	50	-0.4	-4.5	-8.9	-9.9	-9.2
Mean	0.3	-1.8	-2.5	-4.1	-5.3	Mean	0.3	-0.3	-3.7	-4.9	-5.3
TEMPERATURES						TEMPERATURES					
850	-0.3	2	2.5	-3.2	-4.7	850	-1.2	0.3	0.2	-1.1	-5.4
700	-0.4	-2.9	-3.2	-3	-5.1	700	-0.8	-2.7	-3	-3	-5.1
500	-0.9	-2.4	-1.1	-1.7	-2.2	500	0	-1.4	-2	-1.7	-2.3
300	-1.3	3.7	4.2	5.4	3	300	-1.3	-1	-0.6	0.2	-0.3
250	1.2	-1.7	-1.2	1.3	-3.1	250	0.7	-2.9	-4.6	-3.2	-5
200	0.3	-5.6	-6.4	-6.5	-4.5	200	0	-6.7	-8.6	-9.8	-7.7
100	-0.3	-1.7	-7.5	-8	-2.5	100	0.1	-4.1	-8.5	-9.7	-6.4
50	0.3	-1.6	-2.2	-3.1	-5	50	0.1	-2.3	-4	-5.3	-5.7
Mean	-0.2	-1.3	-1.9	-2.3	-3	Mean	-0.3	-2.6	-3.9	-4.2	-4.7
WINDS						WINDS					
850	1.5	0.9	-0.6	-6.3	-12.6	850	1.9	-4.1	-5.5	-7.2	-11.1
700	0	2.8	1.8	-2	-9.6	700	0.8	-1	-1.8	-3.9	-7.2
500	0.2	4.8	4.6	0.4	-7.5	500	0.2	1.2	0.1	-1.4	-5.7
400	-0.2	2.8	2	-0.1	-7	400	-0.2	-0.1	-0.6	-1.7	-5
300	-0.6	-3.4	-2.2	-2.9	-6.1	300	-0.5	-3.1	-1.6	-2.6	-3.8
250	-0.8	-2.9	-3.6	-3.1	-4.9	250	-0.4	-1.9	-1.3	-1.9	-2.8
200	-0.6	-6.2	-5.5	-6	-4.8	200	-0.2	-5	-2.8	-3.3	-2.7
100	-0.6	-6.8	-9.7	-11.1	-8.6	100	-1.6	-16.2	-19.1	-18.2	-11.9
Mean	-0.1	-1	-1.6	-3.9	-7.6	Mean	0	-3.8	-4.1	-5	-6.3
RH						RH					
850	0	-2.1	-2.1	-2.6	-0.2	850	-1.7	-1.8	-2.4	-3.1	-1.9
700	0.5	0.6	-1.5	-2.3	-4.2	700	-0.3	-0.8	-2.7	-2.2	-3.2
500	-0.8	-1.1	-1.6	-0.8	-4.8	500	-0.5	-1.8	-2.3	-2	-3.4
Mean	-0.1	-0.9	-1.7	-1.9	-3.1	Mean	-0.8	-1.5	-2.5	-2.4	-2.8
SURF						SURF					
-pmsl	-3.1	1.6	-2.5	-1.1	-1.6	-pmsl	-0.7	-1.3	-4.6	-3	-3.3
-temp	-5.5	-7.2	-8.1	-4.9	-5.2	-temp	-8.2	-9	-9.5	-7.9	-7.2
-wind	-0.6	-3	-4.9	-6.3	-9.4	-wind	-3.5	-7.5	-9	-10.1	-11.9
Mean	-3.1	-2.9	-5.2	-4.1	-5.4	Mean	-4.1	-5.9	-7.7	-7	-7.5
Mean all	-0.3	-1.4	-2.3	-3.3	-5.1	Mean all	-0.5	-2.5	-4.1	-4.7	-5.4

TABLE A.1

%RMS CHANGE (TRIAL-OPERATIONAL), PERIOD 31/10/94-23/11/94											
VERIFICATION AGAINST OBSERVATIONS											
	T+0	T+24	T+48	T+72	T+120		T+0	T+24	T+48	T+72	T+120
AREA	300, Tropics 30N to 30S					AREA	400, S Hem from 30S				
HEIGHTS						HEIGHTS					
850	0.7	3.2	-2.1	2.1	0.1	850	2	-6.2	-6.8	-8.9	-3.6
700	0.1	13.2	16.5	22.7	20.5	700	0.2	-5.1	-6.1	-8.2	-4
500	0.7	9.1	10.5	13.6	12.8	500	-1.4	-3.1	-3.2	-3.5	-3.9
300	-0.1	6.9	8	10.2	9	300	-1	-1.8	-2	-1.9	-2.3
250	0.9	7.5	9.1	10.4	8.8	250	-0.9	-1.9	-1.5	-1.6	-2.6
200	-0.1	5.5	6.6	7.5	6.8	200	-0.5	-1.8	-1.3	-1.4	-2.8
100	0	1.2	0.2	0.4	0.6	100	0.1	0.3	1	-0.1	-2.2
50	-0.4	-1.7	-2.8	-2.8	-2.9	50	0	-1.3	-1.3	-3.6	-3.8
Mean	0.2	5.6	5.7	8	7	Mean	-0.2	-2.6	-2.6	-3.6	-3.1
TEMPERATURES						TEMPERATURES					
850	0.1	-0.4	-3.1	-1.7	-1.7	850	0.7	-0.1	-0.5	2	-2.2
700	0.2	0.3	-0.7	-0.6	-3.6	700	0.1	1.5	1	3.2	-1
500	-0.9	0	-0.9	-1.1	-4.6	500	0.5	-0.6	0.2	1.9	1.4
300	1.2	0.4	-1.3	0.2	-3.4	300	-1.8	-3.6	-4.2	2.4	1.3
250	0	0.6	-0.8	-0.7	-3.3	250	-0.8	-1.8	-2.2	-0.7	-1
200	0	-0.9	-1.9	-2.1	-2.8	200	0.5	-0.9	-0.9	-2.7	-3.2
100	0.2	1	0.7	0.6	-0.8	100	0.2	-2.2	-3.1	-3.9	-5
50	0.3	-1	0.2	0	-1.1	50	0.9	-0.4	-1.1	-2.8	-2.2
Mean	0.1	0	-1	-0.7	-2.7	Mean	0	-1	-1.3	-0.1	-1.5
WINDS						WINDS					
850	1.5	-5	-7.4	-7.3	-6.9	850	3.3	-5.6	-7.9	-7.1	-6.4
700	1.4	-2.1	-3.7	-4.1	-1.8	700	2	-2.7	-5.3	-4.8	-4.6
500	-0.6	-0.1	0.6	-0.2	-2.8	500	-0.2	-6	-8.3	-5.3	-2.7
400	-0.6	-0.6	1.8	0	-1.3	400	-0.3	-4.4	-7.5	-3.7	-1.5
300	0.1	1.4	4.9	3.9	0.1	300	-1	-2.4	-5.7	-2.4	-1.4
250	0	2.8	5.3	3.8	1.1	250	-0.6	-1	-3.1	-1.3	-1.2
200	0.4	4.1	6.8	5.9	0.7	200	0.1	-3.5	-4	-1.5	-1.1
100	0	0.5	0	-1.1	-2.5	100	-2	-2.4	-1.7	-0.8	0.5
Mean	0.3	0.1	1	0.1	-1.7	Mean	0.2	-3.5	-5.4	-3.4	-2.3
RH						RH					
850	0.2	-1.2	-3.1	-1.9	0	850	-4.6	-1.7	-1.3	0.2	1.1
700	-0.4	-1	-1.5	-1.2	-1.9	700	-2	-1.4	-1.4	0.2	0.1
500	-0.3	0.5	-0.7	-0.7	-2.9	500	-1.7	-1.6	-0.1	1.7	-0.6
Mean	-0.2	-0.6	-1.8	-1.3	-1.6	Mean	-2.8	-1.6	-0.9	0.7	0.2
SURF						SURF					
-pmsl	0.1	0.3	-4.3	-0.7	-2.4	-pmsl	1.1	-4.9	-4.6	-3.6	-1.6
-temp	-4.8	-3	-4	-4.3	-5.6	-temp	-5.3	-3.4	-2	-2.2	-6.5
-wind	-3.7	-5.6	-6.6	-7.2	-8	-wind	2.3	-1.6	-4.4	-5.1	-6.3
Mean	-2.8	-2.8	-5	-4.1	-5.3	Mean	-0.6	-3.3	-3.7	-3.6	-4.8
Mean all	-0.1	1.2	0.9	1.5	0	Mean all	-0.3	-2.4	-3	-2.2	-2.3

TABLE A.2

RMSE	%CHANGE	(TRIAL-OPERATIONAL)	PERIOD 31/10/94-23/11/94				
	T+24	T+72	T+120		T+24	T+72	T+120
VERIFICATION AGAINST ANALYSES							
AREA	2			N.HEM			
HEIGHT				HEIGHT			
850	-2.7	-2.1	-5.1	850	-12.6	-9.6	-8.2
700	0.0	-0.5	-5.4	700	-8.9	-7.3	-7.4
500	2.8	1.6	-5.8	500	-3.4	-4.0	-5.7
300	-0.8	1.4	-5.6	300	-2.4	-1.6	-3.7
250	-1.5	1.7	-5.4	250	-2.0	-0.7	-3.2
200	-2.1	2.7	-5.2	200	-1.3	-0.2	-3.2
100	-5.9	-1.9	-8.7	100	-8.2	-9.4	-8.5
50	-7.2	-6.3	-10.3	50	-8.5	-9.1	-6.5
Mean	-2.2	-0.4	-6.4	Mean	-5.9	-5.2	-5.8
TEMP				TEMP			
850	1.6	2.3	-0.3	850	-1.5	-0.4	-2.3
700	-1.7	3.5	-1.0	700	-2.4	0.4	0.0
500	-1.8	3.3	-2.5	500	-0.9	1.2	-0.3
300	3.6	7.8	3.6	300	0.8	1.3	0.3
250	0.0	4.5	1.5	250	-2.1	-2.6	-3.8
200	-2.9	-2.7	-4.9	200	-5.8	-7.5	-7.4
100	-4.9	-6.6	-6.3	100	-11.0	-10.9	-7.4
50	-3.8	-7.2	-8.7	50	-7.2	-8.5	-6.6
Mean	-1.2	0.6	-2.3	Mean	-3.8	-3.4	-3.4
WIND				WIND			
850	-4.3	-4.7	-7.6	850	-11.9	-8.7	-8.5
700	0.3	-1.9	-7.1	700	-5.6	-5.7	-6.4
500	2.5	0.8	-5.4	500	-1.9	-2.2	-4.6
400	0.9	1.3	-5.3	400	-2.1	-1.4	-4.0
300	-1.6	0.1	-5.2	300	-2.7	-1.1	-3.0
250	-0.8	0.0	-5.0	250	-1.5	-0.1	-2.5
200	-1.2	-0.3	-5.1	200	-2.6	-0.5	-2.8
100	-9.6	-9.3	-11.2	100	-20.2	-18.1	-13.4
Mean	-1.7	-1.8	-6.5	Mean	-6.1	-4.7	-5.7
RELHUM				RELHUM			
950	-8.9	-4.1	-1.9	950	-5.0	-2.4	-1.0
850	-1.6	-2.2	-0.7	850	-1.7	-3.2	-2.4
700	0.7	0.8	-1.4	700	-0.7	-0.1	-0.3
500	-0.2	0.2	-2.7	500	-1.3	-0.8	-1.8
Mean	-2.5	-1.3	-1.7	Mean	-2.2	-1.6	-1.4
PMSL	-1.5	-0.9	-3.2	PMSL	-10.9	-7.6	-6.6

TABLE A.3

RMSE	%CHANGE	(TRIAL-OPERATIONAL)	PERIOD 31/10/94-23/11/94				
	T+24	T+72	T+120		T+24	T+72	T+120
VERIFICATION AGAINST ANALYSES							
TROPICS				S.HEM			
HEIGHT				HEIGHT			
850	3.4	8.1	9.1	850	-5.8	-6.0	-3.8
700	11.2	22.6	22.8	700	-4.0	-5.9	-4.1
500	15.9	21.4	19.9	500	-2.1	-4.4	-3.4
300	14.4	15.0	11.9	300	-1.6	-3.1	-2.4
250	14.5	15.9	12.5	250	-1.3	-2.6	-2.1
200	14.7	16.2	13.4	200	0.0	-1.9	-1.8
100	9.2	10.5	9.5	100	0.4	-1.2	-3.0
50	2.5	4.0	3.2	50	-0.3	-2.0	-5.0
Mean	10.7	14.2	12.8	Mean	-1.8	-3.4	-3.2
TEMP				TEMP			
850	1.2	-0.7	-1.7	850	0.7	1.1	0.3
700	-1.3	2.1	3.3	700	-0.7	0.4	0.6
500	0.0	0.0	0.0	500	-1.5	-1.1	-0.3
300	0.0	-0.8	-2.5	300	-0.7	0.8	0.9
250	0.0	0.0	-1.6	250	-0.6	-0.3	-0.5
200	-2.3	-1.1	-1.4	200	-1.3	-1.7	-3.2
100	-2.9	-2.7	-3.5	100	-2.8	-3.4	-4.5
50	-1.4	-2.0	-3.3	50	-2.0	-3.6	-5.3
Mean	-0.8	-0.7	-1.3	Mean	-1.1	-1.0	-1.5
WIND				WIND			
850	-6.5	-7.7	-7.5	850	-7.6	-3.7	0.6
700	-1.3	-3.3	-3.4	700	-4.6	-2.5	1.2
500	-0.2	-1.8	-1.9	500	-3.1	-0.7	2.0
400	-0.2	-1.9	-1.8	400	-2.8	-0.1	2.4
300	0.5	-1.1	-1.5	300	-2.5	0.3	3.0
250	0.8	-0.5	-1.5	250	-2.5	0.0	3.4
200	1.2	-0.9	-1.6	200	-3.0	-0.2	4.0
100	-0.2	-0.8	-0.4	Mean	-4.0	-3.6	-1.2
Mean	-0.7	-2.3	-2.5		-3.8	-1.3	1.9
RELHUM				RELHUM			
950	-3.6	-5.5	-5.4	950	-2.3	-2.4	0.4
850	-1.4	-1.6	-1.4	850	0.0	-0.8	-0.5
700	-1.1	-1.4	-0.3	700	0.1	1.5	1.0
500	1.3	-0.4	-1.1	500	0.1	0.5	0.2
Mean	-1.2	-2.2	-2.1	Mean	-0.5	-0.3	0.3
PMSL	0.0	0.0	0.5	PMSL	-6.5	-5.6	-3.5

TABLE A.4

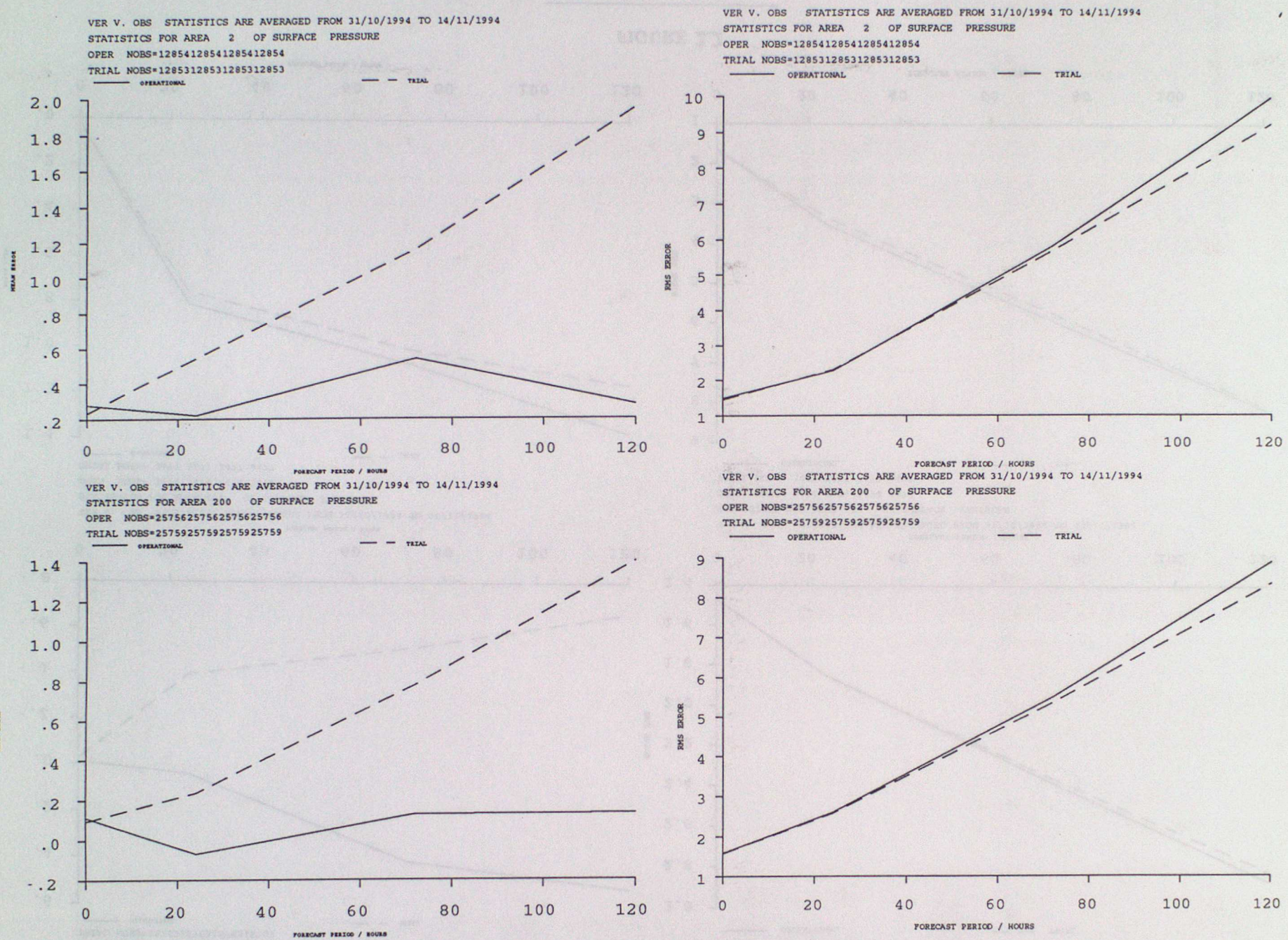

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 2 OF SURFACE PRESSURE
OPER NOBS=12854128541285412854
TRIAL NOBS=12853128531285312853
OPERATIONAL
TRIAL
MEAN ERROR
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 2 OF SURFACE PRESSURE
OPER NOBS=12854128541285412854
TRIAL NOBS=12853128531285312853
OPERATIONAL
TRIAL
RMS ERROR
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 200 OF SURFACE PRESSURE
OPER NOBS=25756257562575625756
TRIAL NOBS=25759257592575925759
OPERATIONAL
TRIAL
MEAN ERROR
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 200 OF SURFACE PRESSURE
OPER NOBS=25756257562575625756
TRIAL NOBS=25759257592575925759
OPERATIONAL
TRIAL
RMS ERROR
FORECAST PERIOD / HOURS

FIGURE 2.1

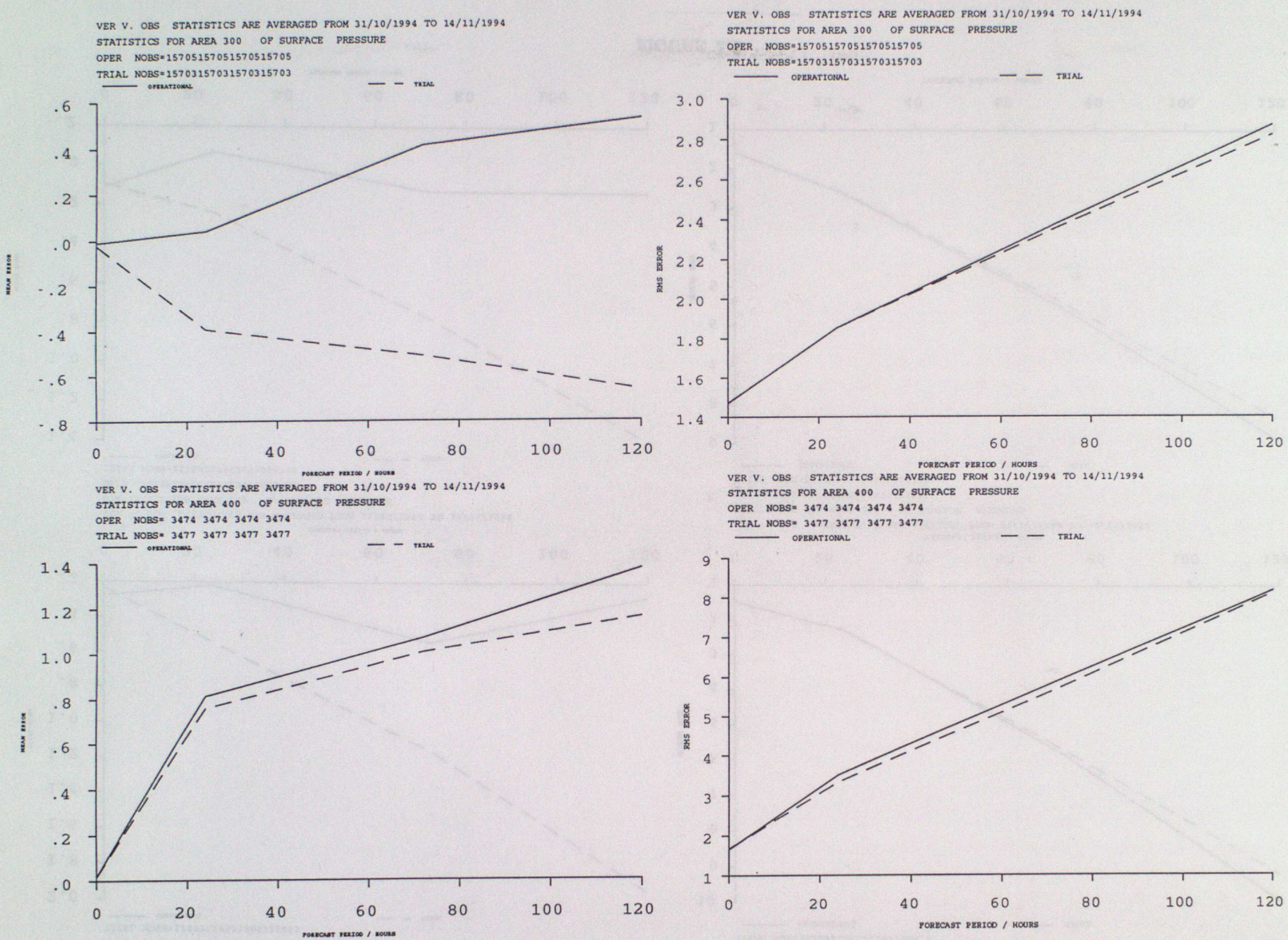
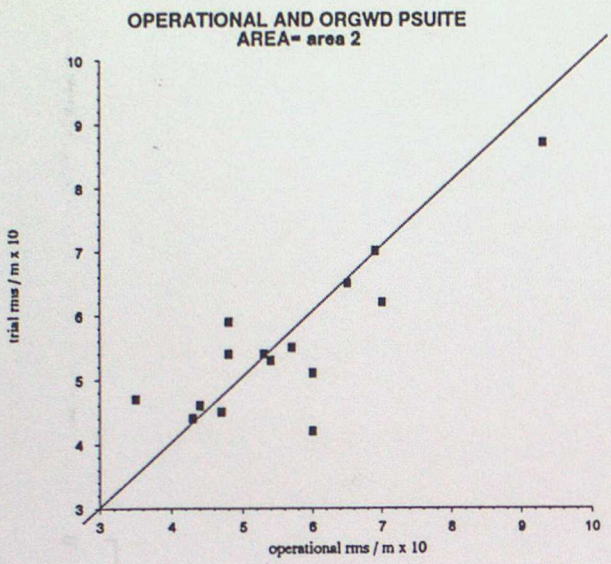
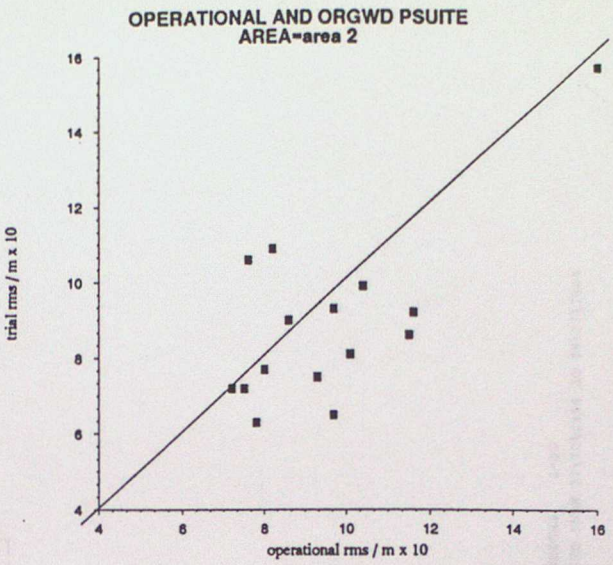

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 300 OF SURFACE PRESSURE
OPER NOBS=15705157051570515705
TRIAL NOBS=15703157031570315703
OPERATIONAL
TRIAL
MEAN ERROR
.6
.4
.2
.0
-.2
-.4
-.6
-.8
0
20
40
60
80
100
120
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 300 OF SURFACE PRESSURE
OPER NOBS=15705157051570515705
TRIAL NOBS=15703157031570315703
OPERATIONAL
TRIAL
RMS ERROR
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
0
20
40
60
80
100
120
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 400 OF SURFACE PRESSURE
OPER NOBS= 3474 3474 3474 3474
TRIAL NOBS= 3477 3477 3477 3477
OPERATIONAL
TRIAL
MEAN ERROR
1.4
1.2
1.0
.8
.6
.4
.2
.0
0
20
40
60
80
100
120
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 400 OF SURFACE PRESSURE
OPER NOBS= 3474 3474 3474 3474
TRIAL NOBS= 3477 3477 3477 3477
OPERATIONAL
TRIAL
RMS ERROR
9
8
7
6
5
4
3
2
1
0
20
40
60
80
100
120
FORECAST PERIOD / HOURS

FIGURE 2.2

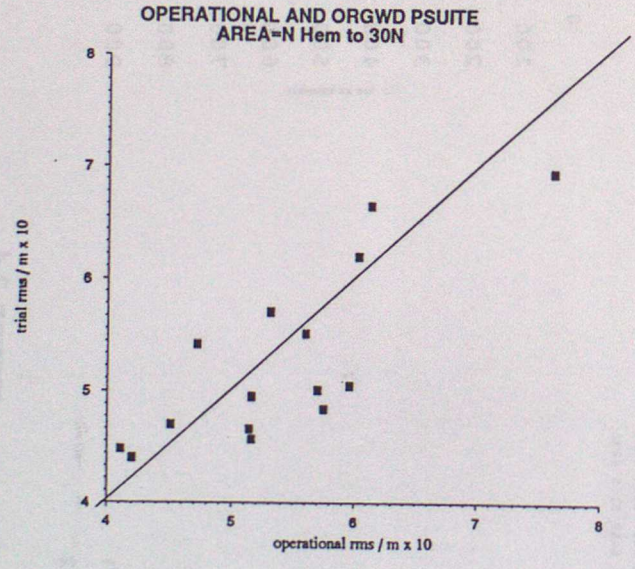
PMSL VERIFICATION AGAINST OBSERVATIONS
T+72



PMSL VERIFICATION AGAINST OBSERVATIONS
T+120



PMSL VERIFICATION AGAINST OBSERVATIONS
T+72



PMSL VERIFICATION AGAINST OBSERVATIONS
T+120

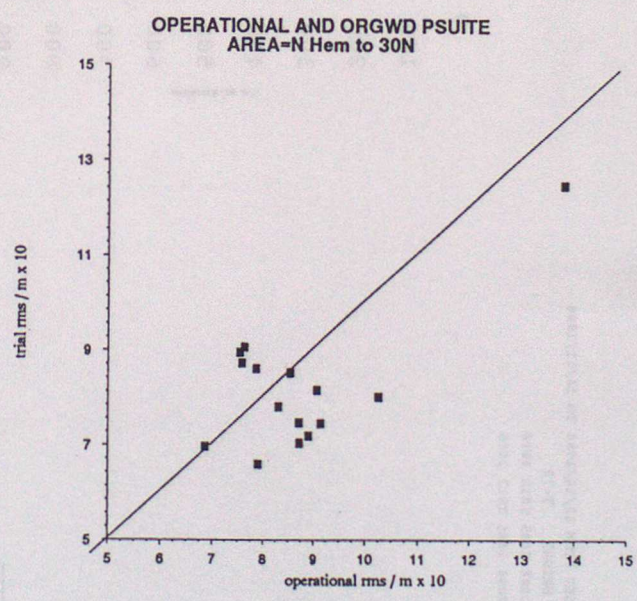
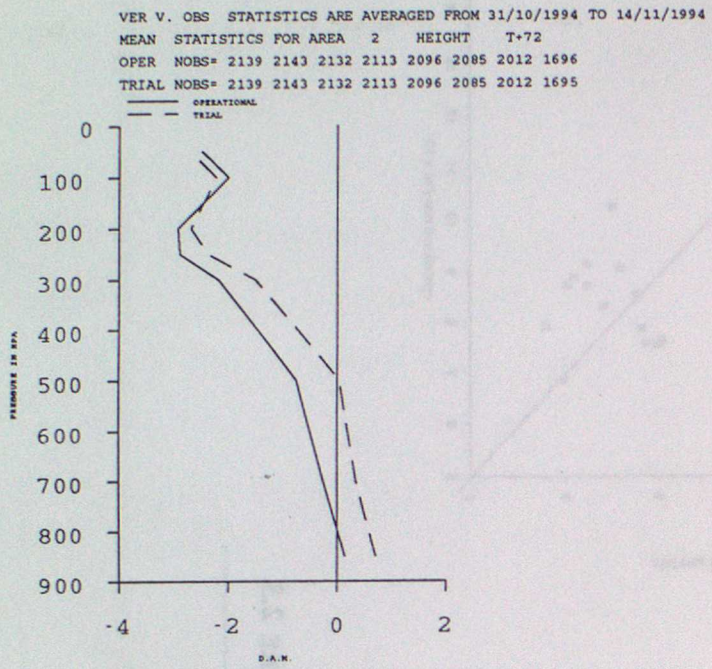
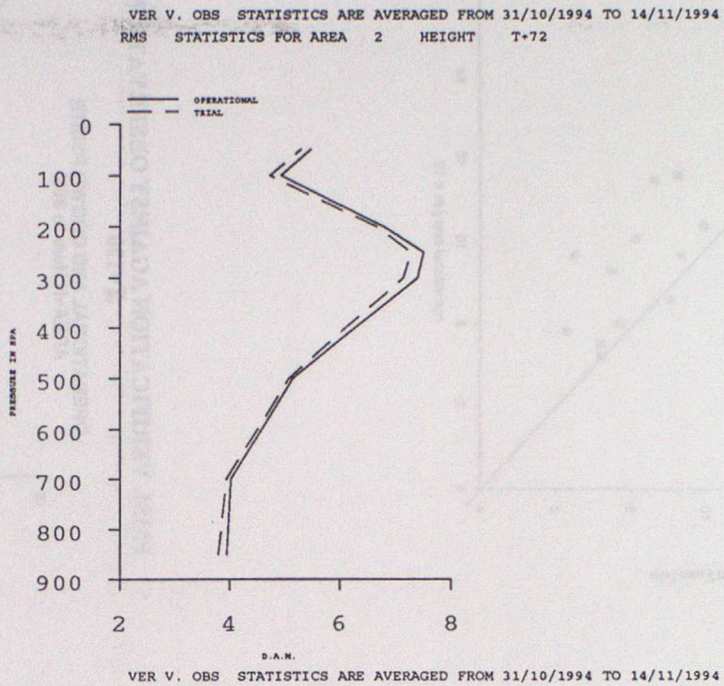
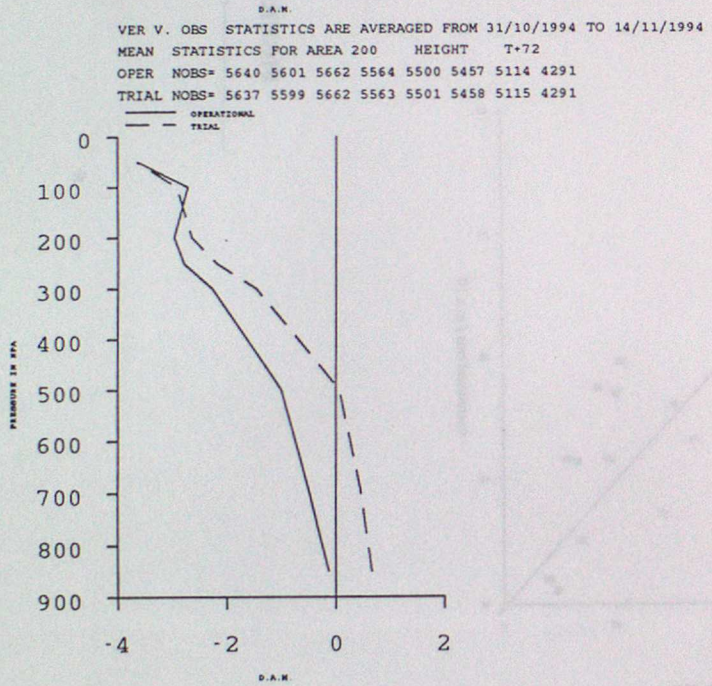


FIGURE 2.3


VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 2 HEIGHT T+72
OPER NOBS= 2139 2143 2132 2113 2096 2085 2012 1696
TRIAL NOBS= 2139 2143 2132 2113 2096 2085 2012 1695
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-4
-2
0
2
D.A.H.


VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 2 HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
2
4
6
8
D.A.H.


VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 200 HEIGHT T+72
OPER NOBS= 5640 5601 5662 5564 5500 5457 5114 4291
TRIAL NOBS= 5637 5599 5662 5563 5501 5458 5115 4291
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-4
-2
0
2
D.A.H.

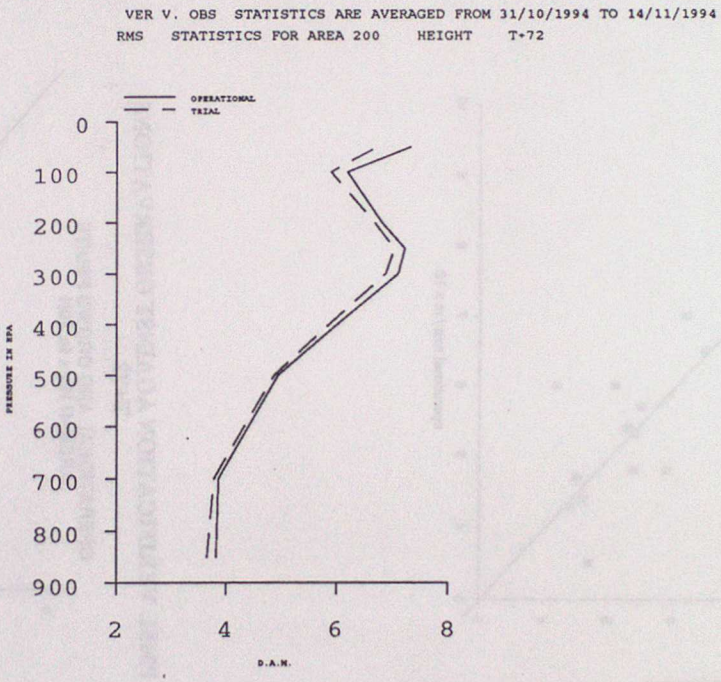

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 200 HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
2
4
6
8
D.A.H.

FIGURE 2.4

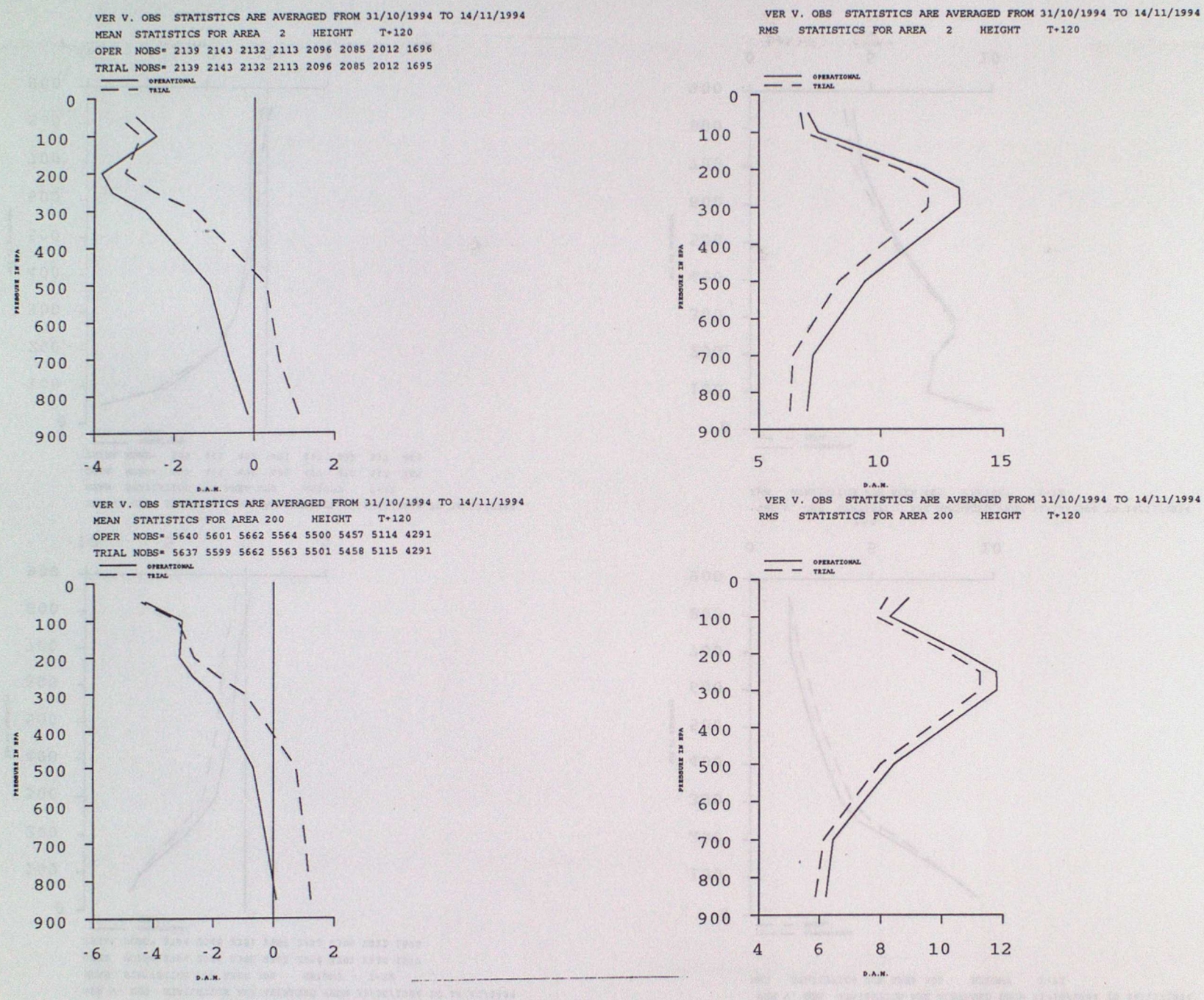

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 2 HEIGHT T+120
OPER NOBS= 2139 2143 2132 2113 2096 2085 2012 1696
TRIAL NOBS= 2139 2143 2132 2113 2096 2085 2012 1695
OPERATIONAL
TRIAL
PRESSURE IN HPA
D.A.N.
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 2 HEIGHT T+120
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 200 HEIGHT T+120
OPER NOBS= 5640 5601 5662 5564 5500 5457 5114 4291
TRIAL NOBS= 5637 5599 5662 5563 5501 5458 5115 4291
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 200 HEIGHT T+120

FIGURE 2.5

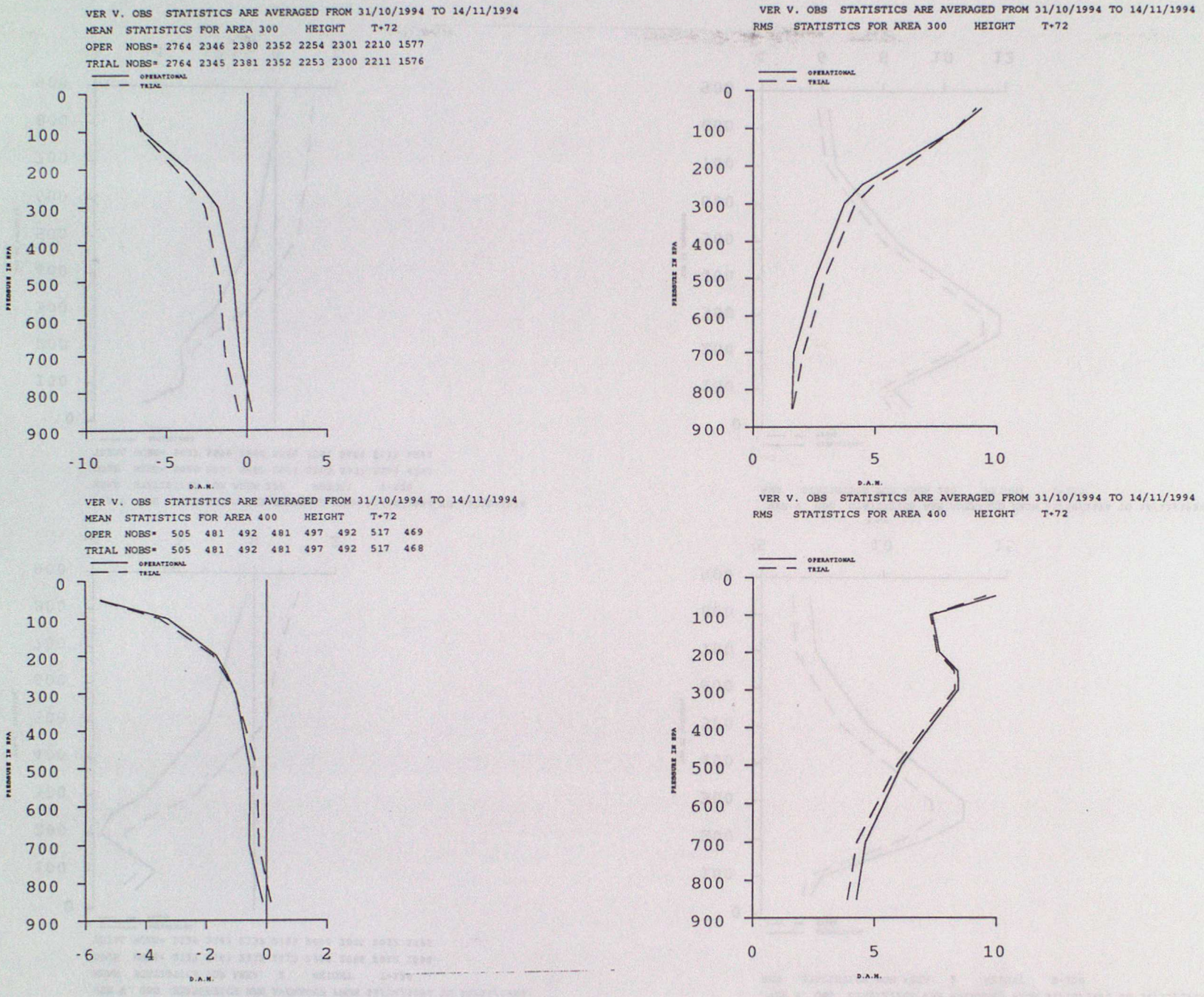

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 300 HEIGHT T+72
OPER NOBS= 2764 2346 2380 2352 2254 2301 2210 1577
TRIAL NOBS= 2764 2345 2381 2352 2253 2300 2211 1576
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-10
-5
0
5
D.A.H.
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 300 HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
0
5
10
D.A.H.
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 400 HEIGHT T+72
OPER NOBS= 505 481 492 481 497 492 517 469
TRIAL NOBS= 505 481 492 481 497 492 517 468
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-6
-4
-2
0
2
D.A.H.
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 400 HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
0
5
10
D.A.H.

FIGURE 2.6

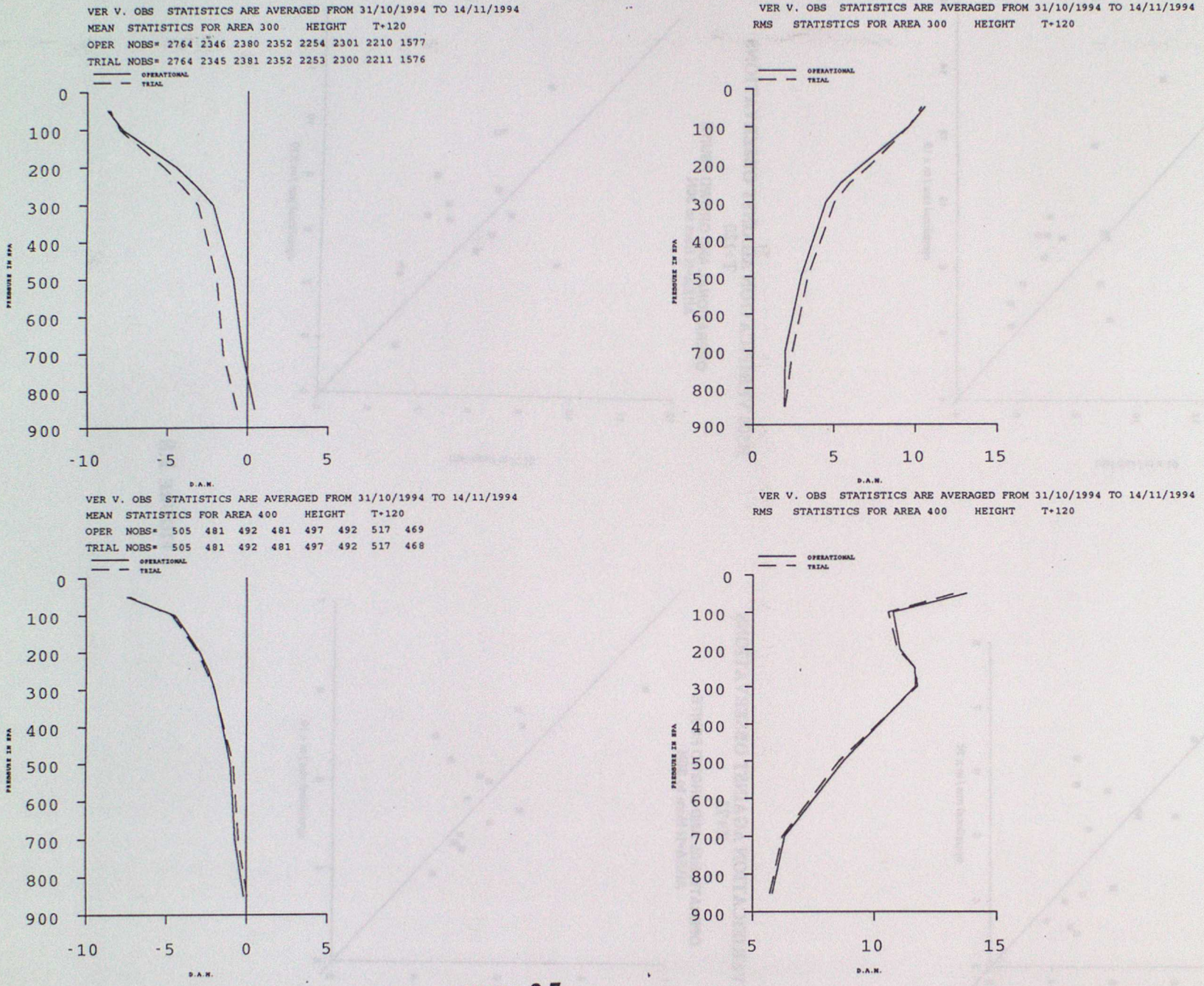
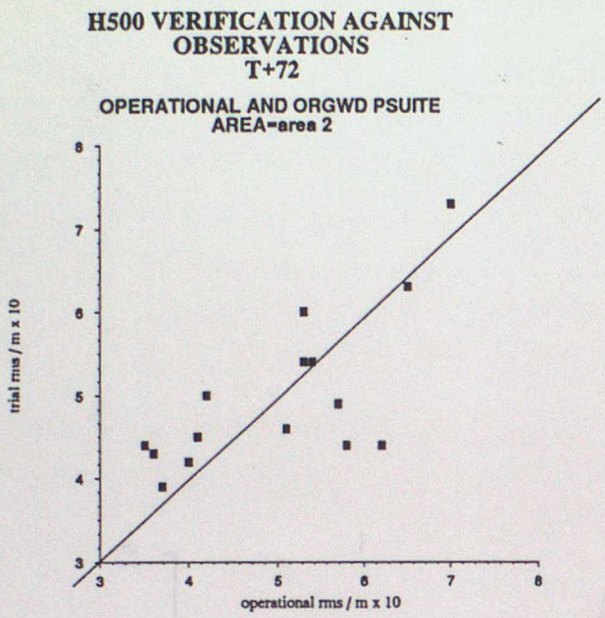
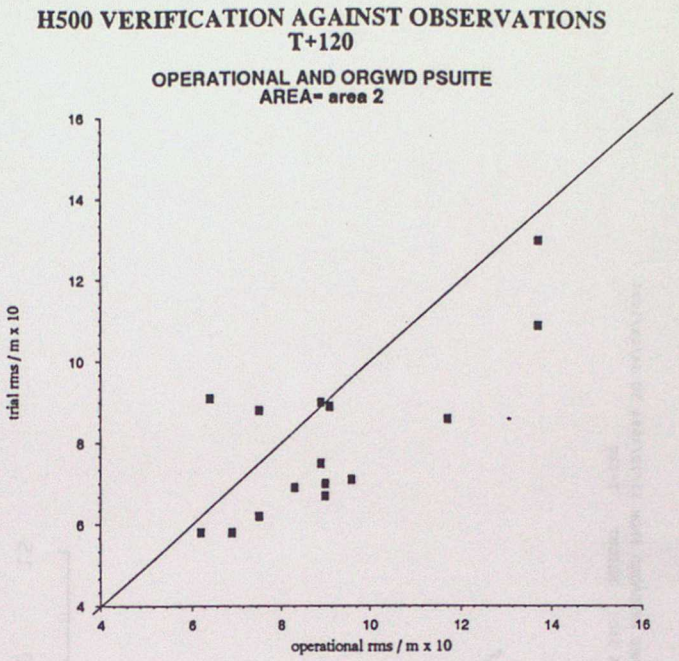
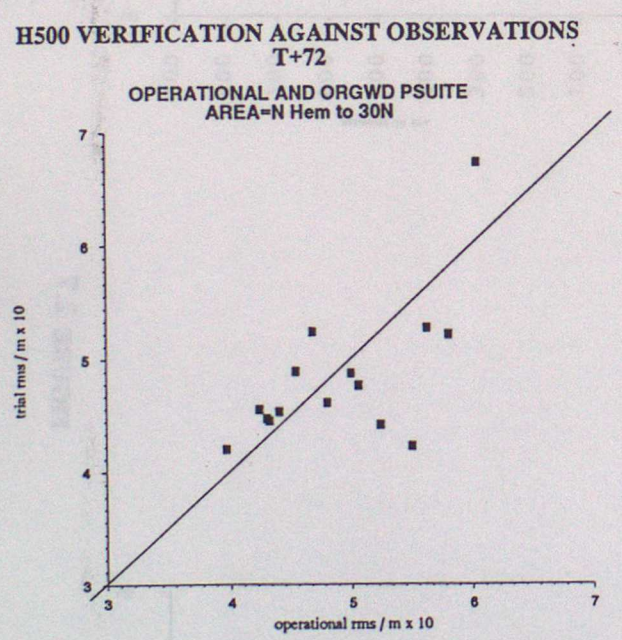

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 300 HEIGHT T+120
OPER NOBS= 2764 2346 2380 2352 2254 2301 2210 1577
TRIAL NOBS= 2764 2345 2381 2352 2253 2300 2211 1576
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-10
-5
0
5
D.A.N.
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 300 HEIGHT T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
0
5
10
15
D.A.N.
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 400 HEIGHT T+120
OPER NOBS= 505 481 492 481 497 492 517 469
TRIAL NOBS= 505 481 492 481 497 492 517 468
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-10
-5
0
5
D.A.N.
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 400 HEIGHT T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
5
10
15
D.A.N.

FIGURE 2.7


H500 VERIFICATION AGAINST OBSERVATIONS
T+72
OPERATIONAL AND ORGWD PSUITE
AREA=area 2
trial rms / m x 10
operational rms / m x 10


H500 VERIFICATION AGAINST OBSERVATIONS
T+120
OPERATIONAL AND ORGWD PSUITE
AREA= area 2
trial rms / m x 10
operational rms / m x 10


H500 VERIFICATION AGAINST OBSERVATIONS
T+72
OPERATIONAL AND ORGWD PSUITE
AREA=N Hem to 30N
trial rms / m x 10
operational rms / m x 10

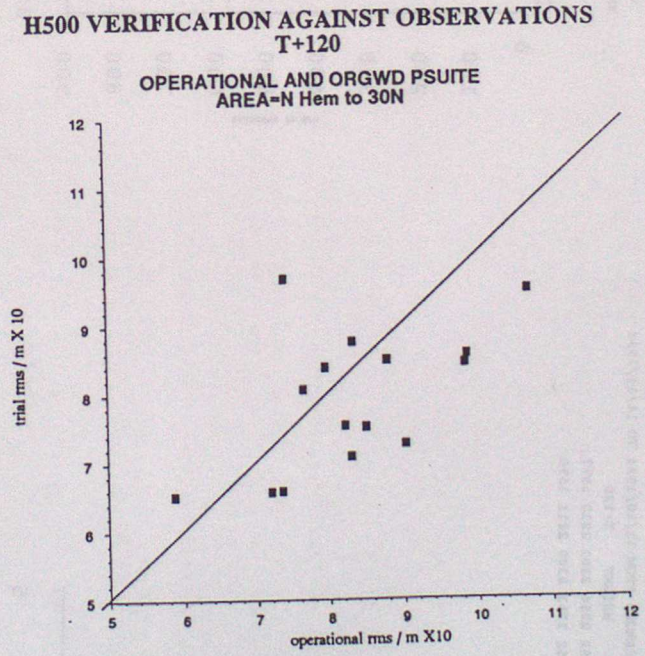
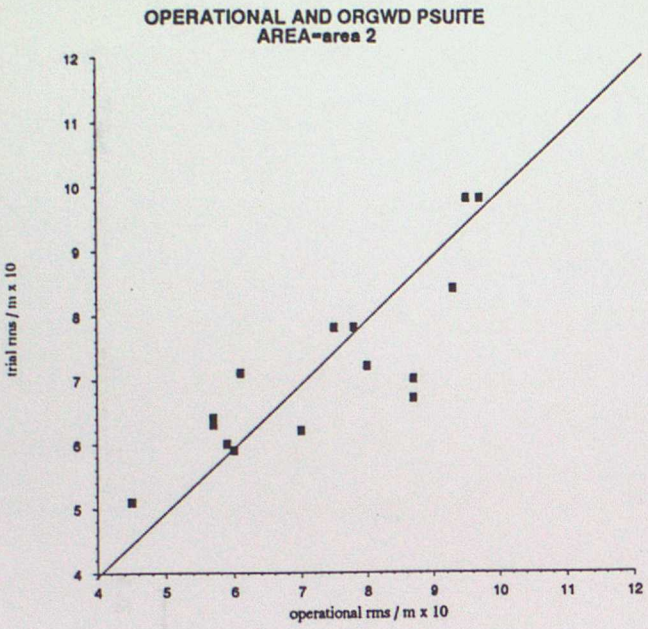
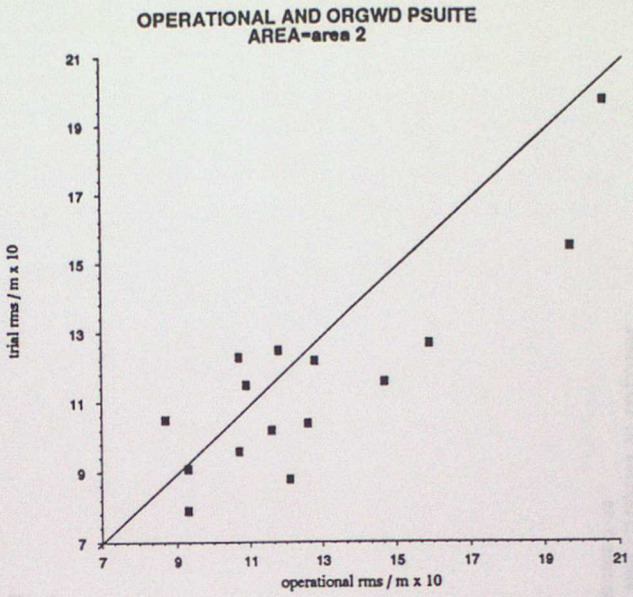

H500 VERIFICATION AGAINST OBSERVATIONS
T+120
OPERATIONAL AND ORGWD PSUITE
AREA=N Hem to 30N
trial rms / m X 10
operational rms / m X10

FIGURE 2.8

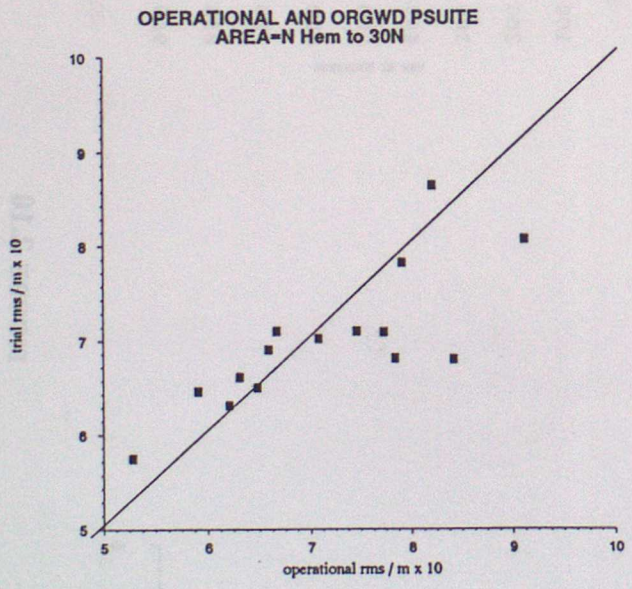
H250 VERIFICATION AGAINST OBSERVATIONS
T+72



H250 VERIFICATION AGAINST OBSERVATIONS
T+120



H250 VERIFICATION AGAINST OBSERVATIONS
T+72



H250 VERIFICATION AGAINST OBSERVATIONS
T+120

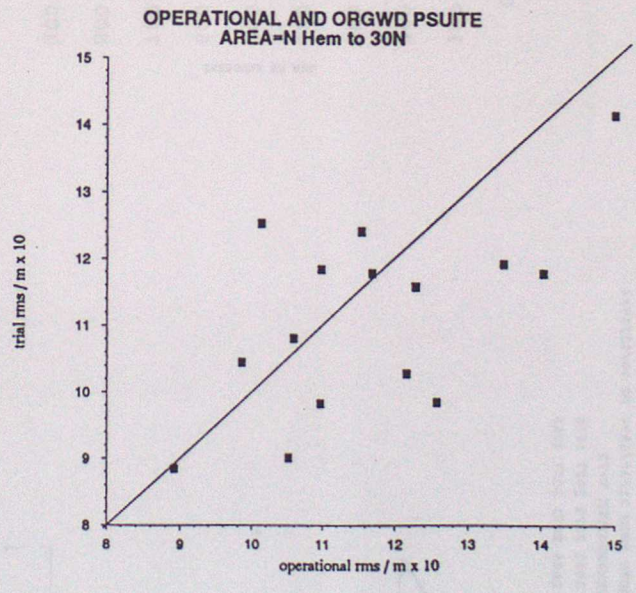
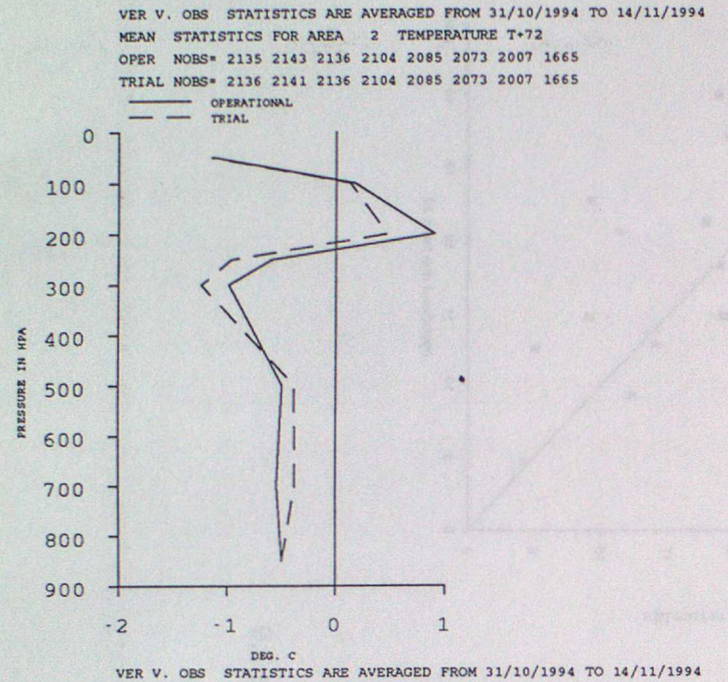
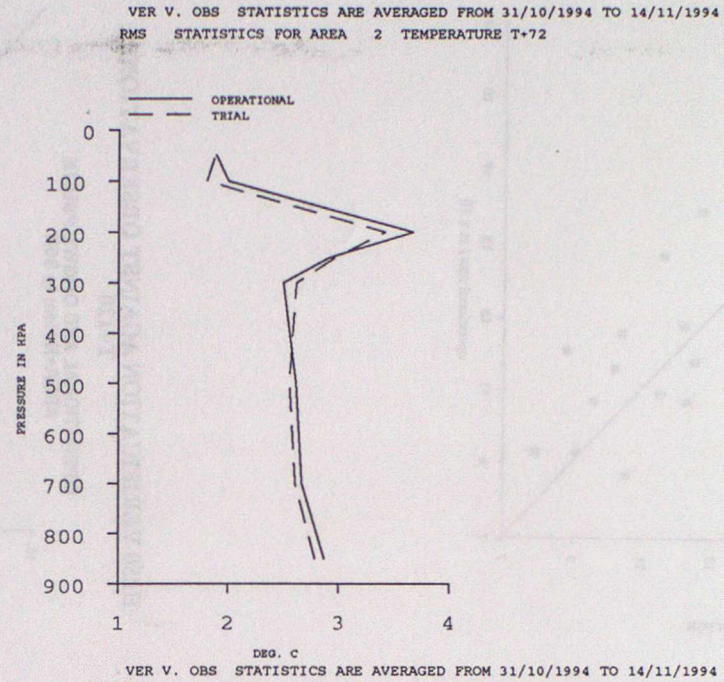
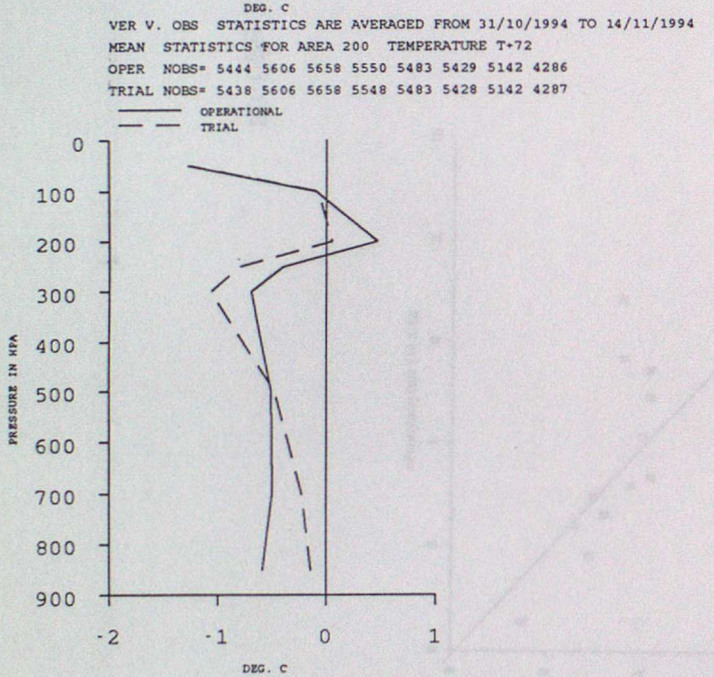


FIGURE 2.9


VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 2 TEMPERATURE T+72
OPER NOBS= 2135 2143 2136 2104 2085 2073 2007 1665
TRIAL NOBS= 2136 2141 2136 2104 2085 2073 2007 1665
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-2
-1
0
1
DEG. C


VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 2 TEMPERATURE T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
1
2
3
4
DEG. C


VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 200 TEMPERATURE T+72
OPER NOBS= 5444 5606 5658 5550 5483 5429 5142 4286
TRIAL NOBS= 5438 5606 5658 5548 5483 5428 5142 4287
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-2
-1
0
1
DEG. C

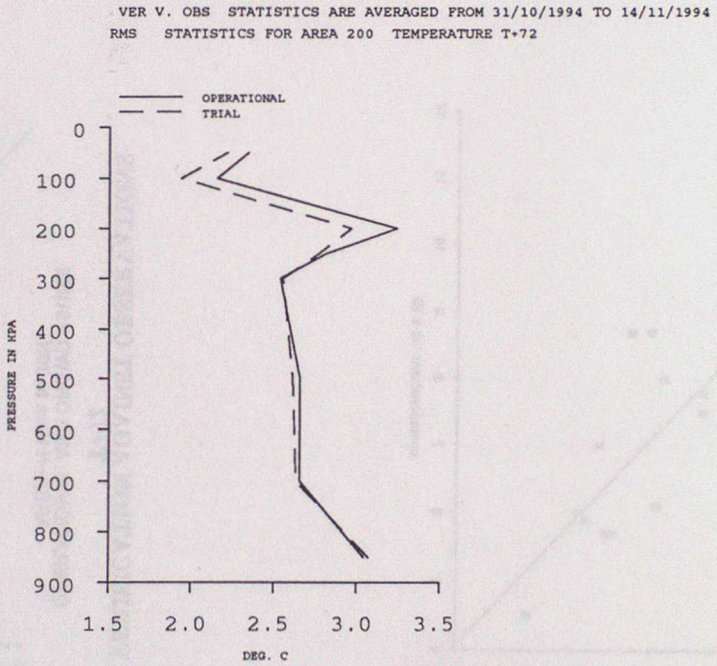

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 200 TEMPERATURE T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
1.5
2.0
2.5
3.0
3.5
DEG. C

FIGURE 2.10

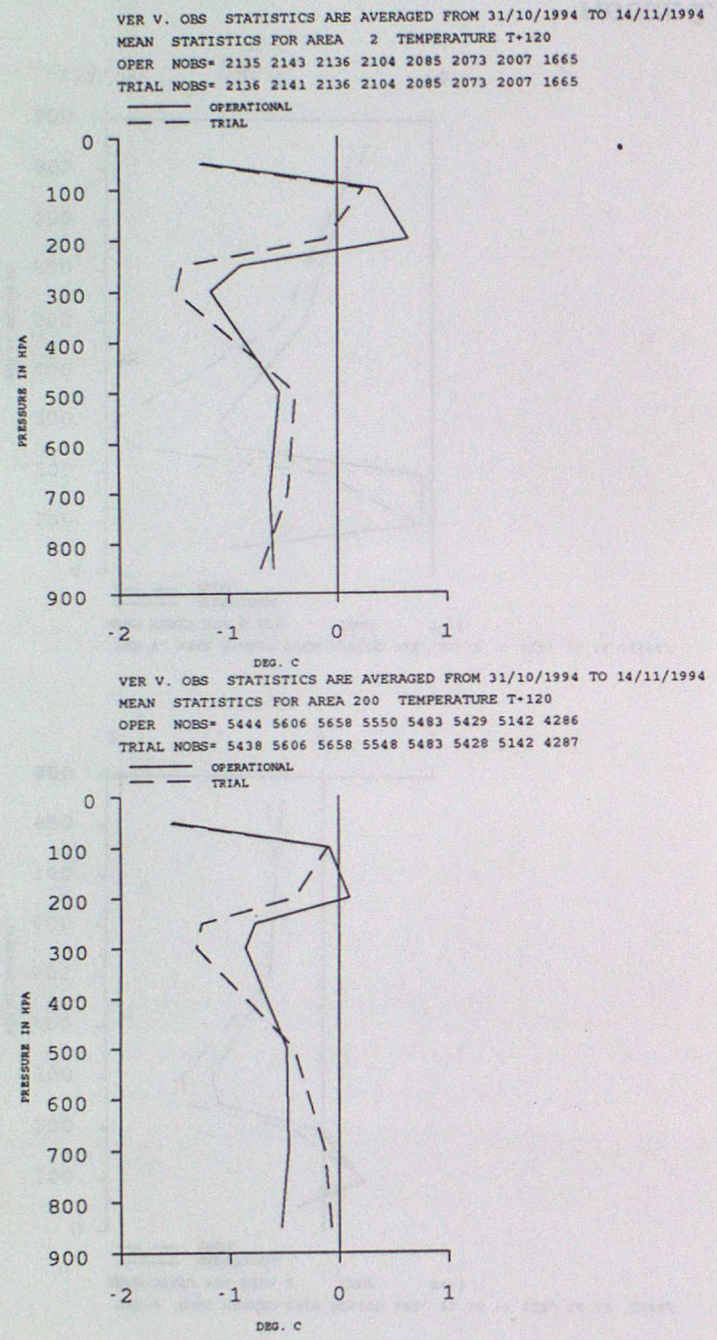
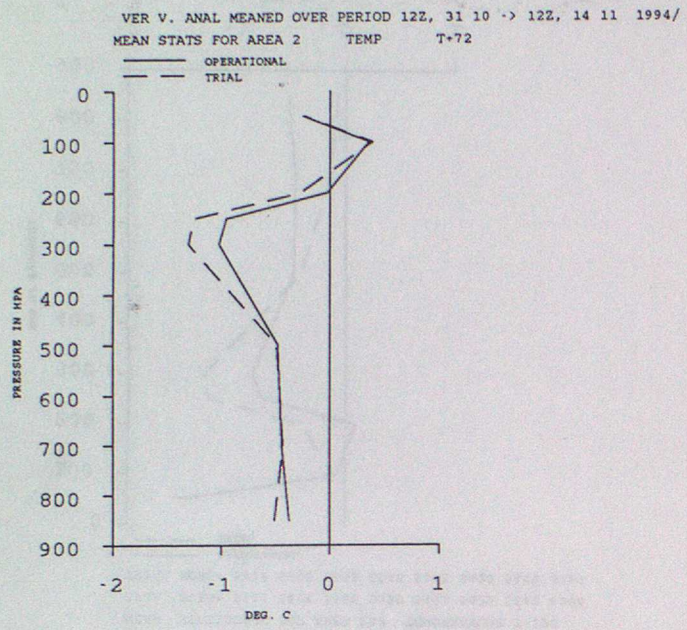
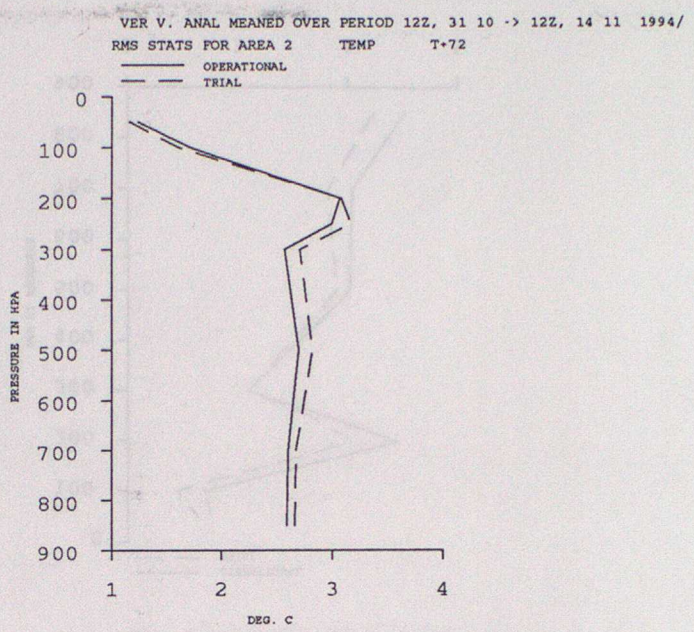
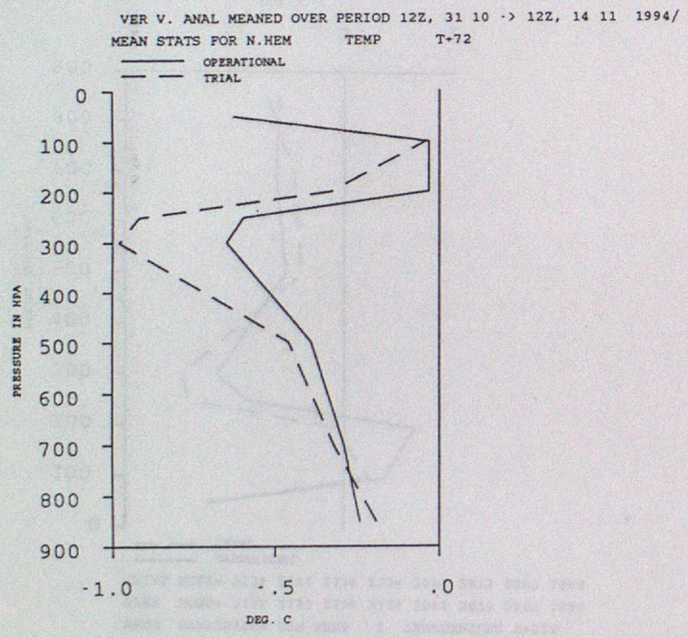

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 2 TEMPERATURE T+120
OPER NOBS= 2135 2143 2136 2104 2085 2073 2007 1665
TRIAL NOBS= 2136 2141 2136 2104 2085 2073 2007 1665
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-2
-1
0
1
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 2 TEMPERATURE T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
2
3
4
5
6
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 200 TEMPERATURE T+120
OPER NOBS= 5444 5606 5658 5550 5483 5429 5142 4286
TRIAL NOBS= 5438 5606 5658 5548 5483 5428 5142 4287
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 200 TEMPERATURE T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C

FIGURE 2.11


VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
MEAN STATS FOR AREA 2 TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-2
-1
0
1
DEG. C


VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
RMS STATS FOR AREA 2 TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
1
2
3
4
DEG. C


VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
MEAN STATS FOR N.HEM TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-1.0
-.5
.0
DEG. C

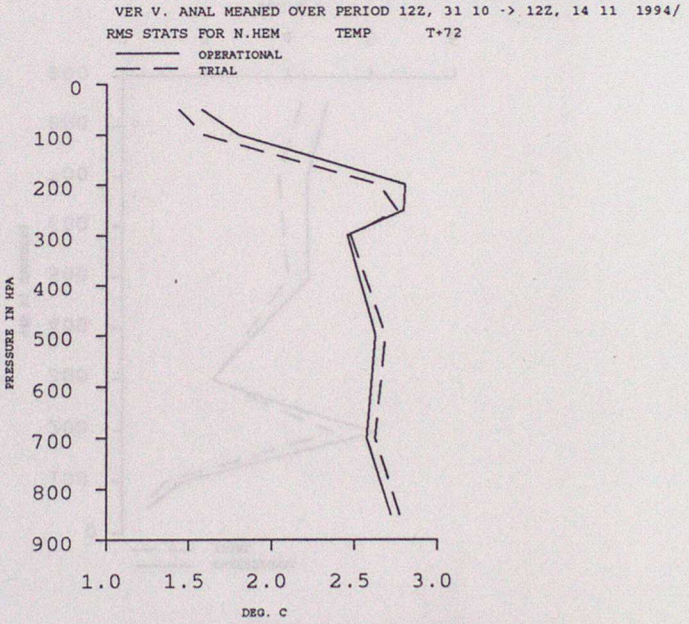

VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
RMS STATS FOR N.HEM TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
1.0
1.5
2.0
2.5
3.0
DEG. C

FIGURE 2.12

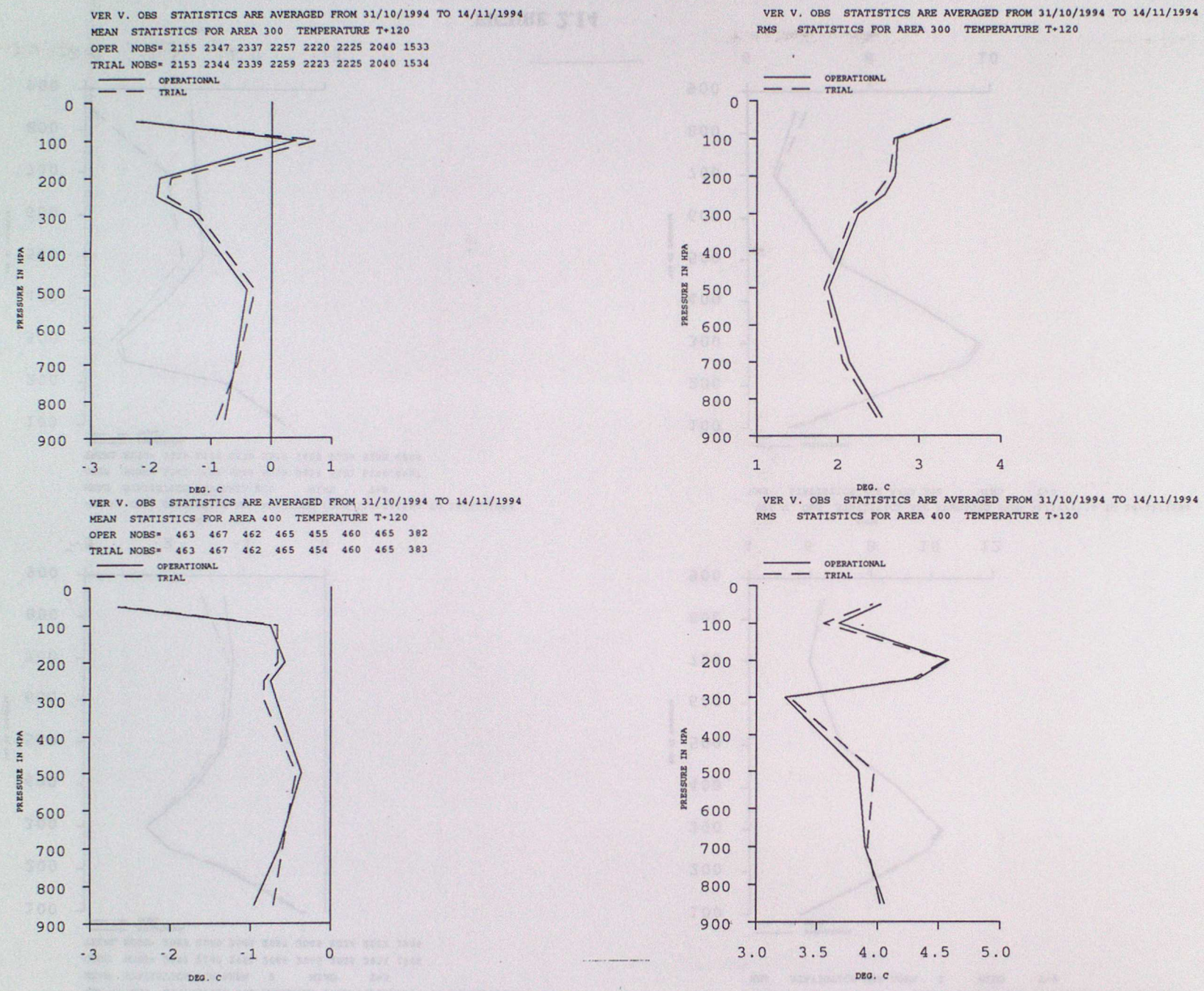

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 300 TEMPERATURE T+120
OPER NOBS= 2155 2347 2337 2257 2220 2225 2040 1533
TRIAL NOBS= 2153 2344 2339 2259 2223 2225 2040 1534
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 300 TEMPERATURE T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 400 TEMPERATURE T+120
OPER NOBS= 463 467 462 465 455 460 465 382
TRIAL NOBS= 463 467 462 465 454 460 465 383
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 400 TEMPERATURE T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
DEG. C

FIGURE 2.13

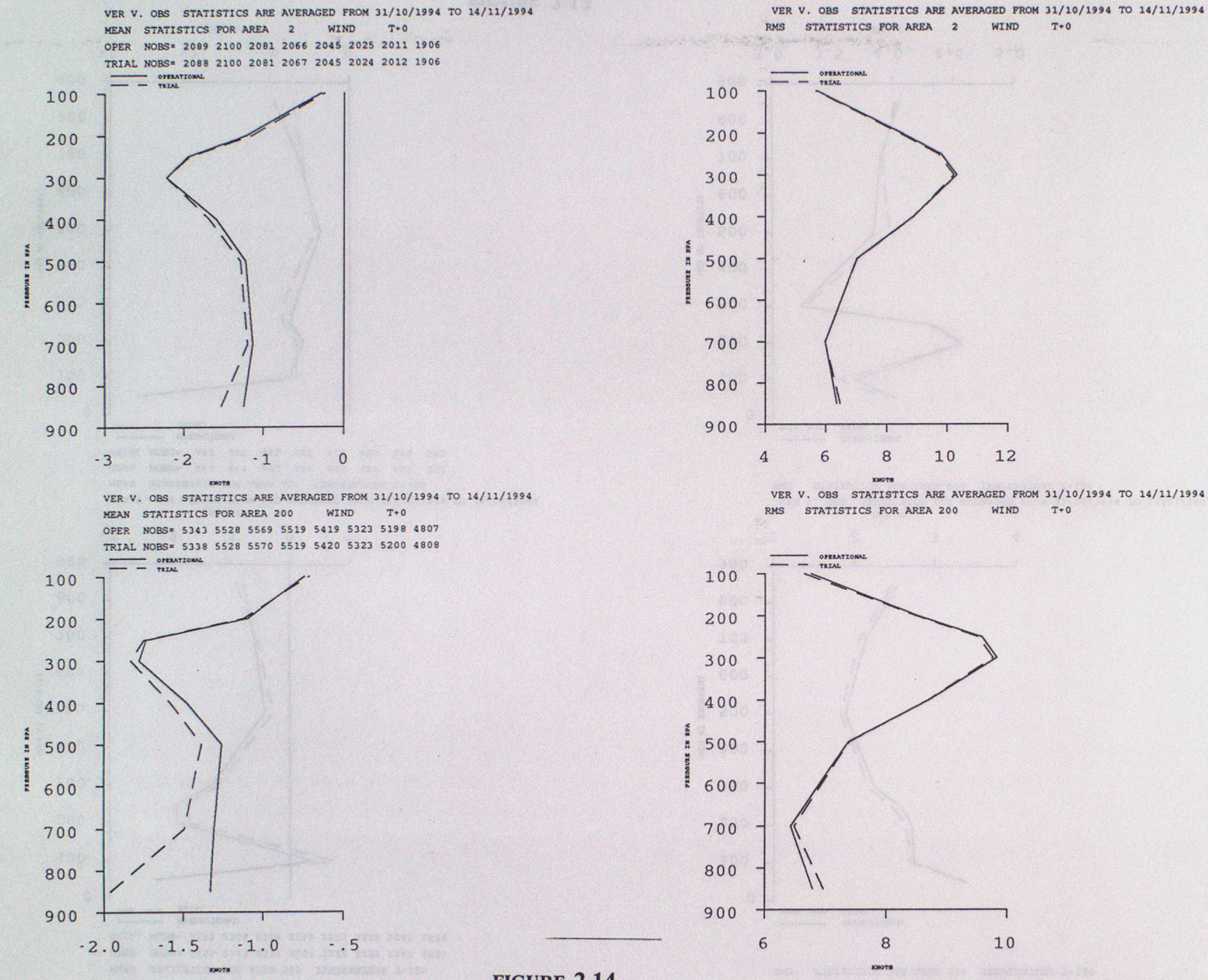

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 2 WIND T+0
OPER NOBS= 2089 2100 2081 2066 2045 2025 2011 1906
TRIAL NOBS= 2088 2100 2081 2067 2045 2024 2012 1906
OPERATIONAL
TRIAL
100
200
300
400
500
600
700
800
900
PRESSURE IN HPA
-3
-2
-1
0
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 2 WIND T+0
OPERATIONAL
TRIAL
100
200
300
400
500
600
700
800
900
PRESSURE IN HPA
4
6
8
10
12
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 200 WIND T+0
OPER NOBS= 5343 5528 5569 5519 5419 5323 5198 4807
TRIAL NOBS= 5338 5528 5570 5519 5420 5323 5200 4808
OPERATIONAL
TRIAL
100
200
300
400
500
600
700
800
900
PRESSURE IN HPA
-2.0
-1.5
-1.0
-.5
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 200 WIND T+0
OPERATIONAL
TRIAL
100
200
300
400
500
600
700
800
900
PRESSURE IN HPA
6
8
10
KNOTS

FIGURE 2.14

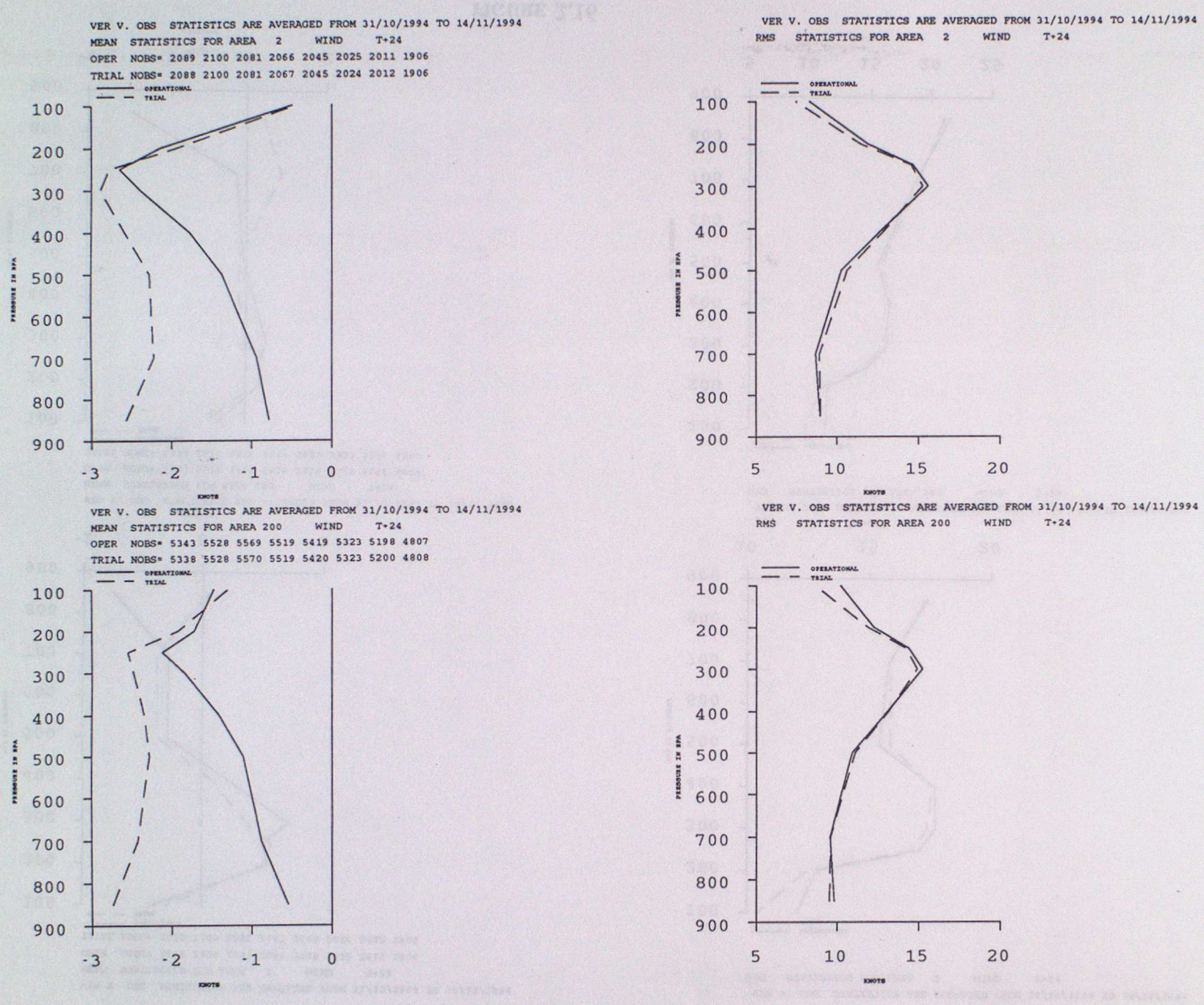

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 2 WIND T+24
OPER NOBS= 2089 2100 2081 2066 2045 2025 2011 1906
TRIAL NOBS= 2088 2100 2081 2067 2045 2024 2012 1906
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-3
-2
-1
0
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 2 WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
5
10
15
20
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 200 WIND T+24
OPER NOBS= 5343 5528 5569 5519 5419 5323 5198 4807
TRIAL NOBS= 5338 5528 5570 5519 5420 5323 5200 4808
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-3
-2
-1
0
KNOTS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 200 WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
5
10
15
20
KNOTS

FIGURE 2.15

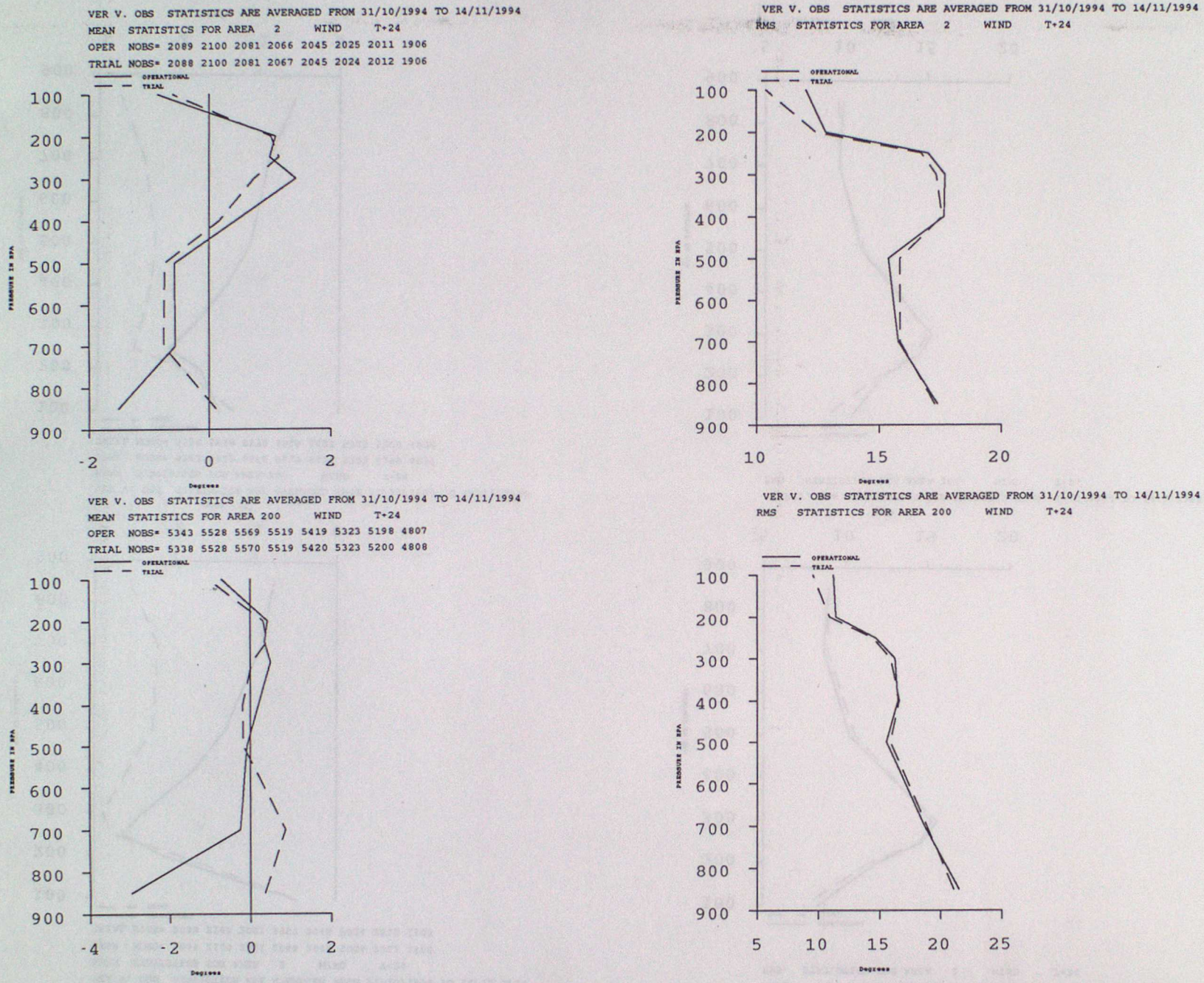
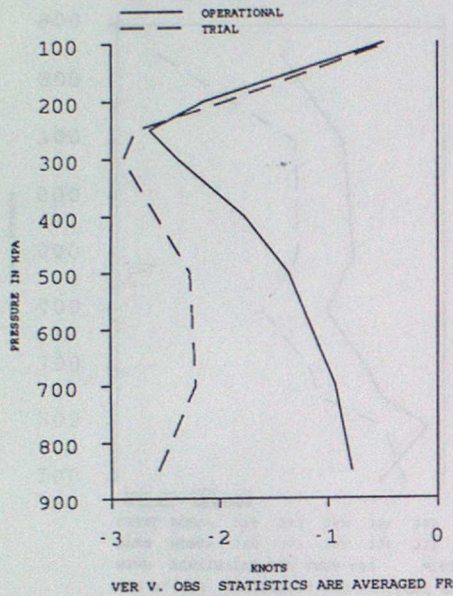
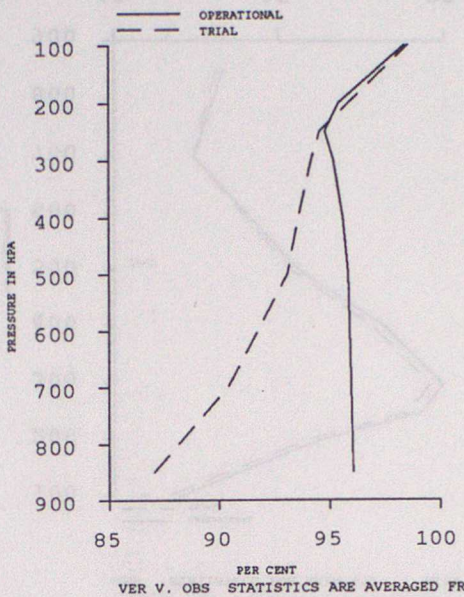

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 2 WIND T+24
OPER NOBS= 2089 2100 2081 2066 2045 2025 2011 1906
TRIAL NOBS= 2088 2100 2081 2067 2045 2024 2012 1906
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-2
0
2
Degrees
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 2 WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
10
15
20
Degrees
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 200 WIND T+24
OPER NOBS= 5343 5528 5569 5519 5419 5323 5198 4807
TRIAL NOBS= 5338 5528 5570 5519 5420 5323 5200 4808
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-4
-2
0
2
Degrees
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 200 WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
5
10
15
20
25
Degrees

FIGURE 2.16

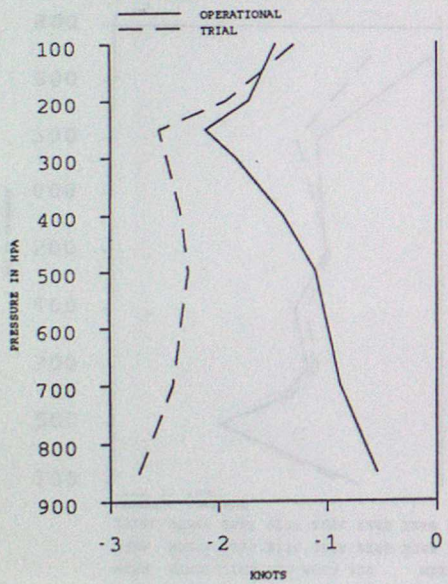
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 2 WIND T+24
OPER NOBS= 2089 2100 2081 2066 2045 2025 2011 1906
TRIAL NOBS= 2088 2100 2081 2067 2045 2024 2012 1906



VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
% OBS WIND STATISTICS FOR AREA 2 WIND T+24



VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 200 WIND T+24
OPER NOBS= 5343 5528 5569 5519 5419 5323 5198 4807
TRIAL NOBS= 5338 5528 5570 5519 5420 5323 5200 4808



VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
% OBS WIND STATISTICS FOR AREA 200 WIND T+24

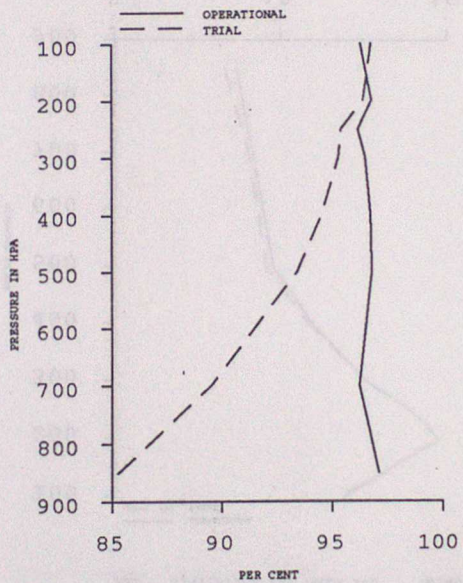
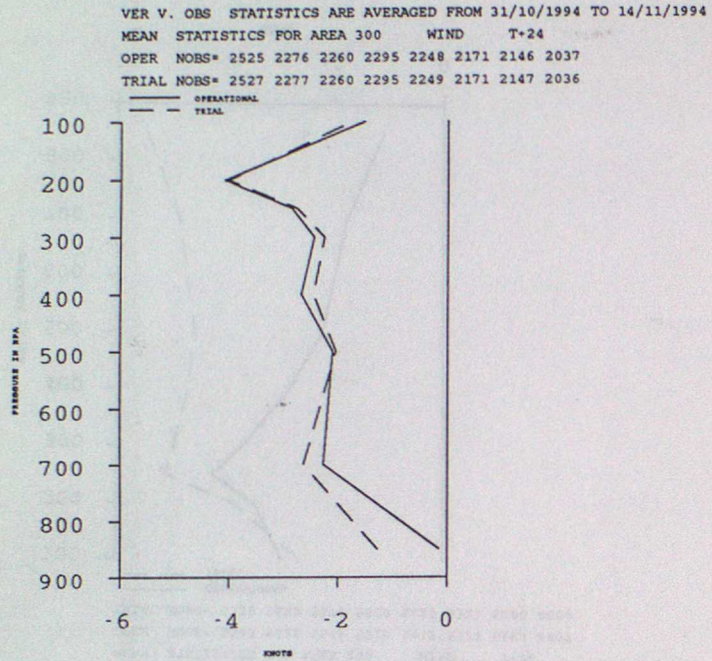
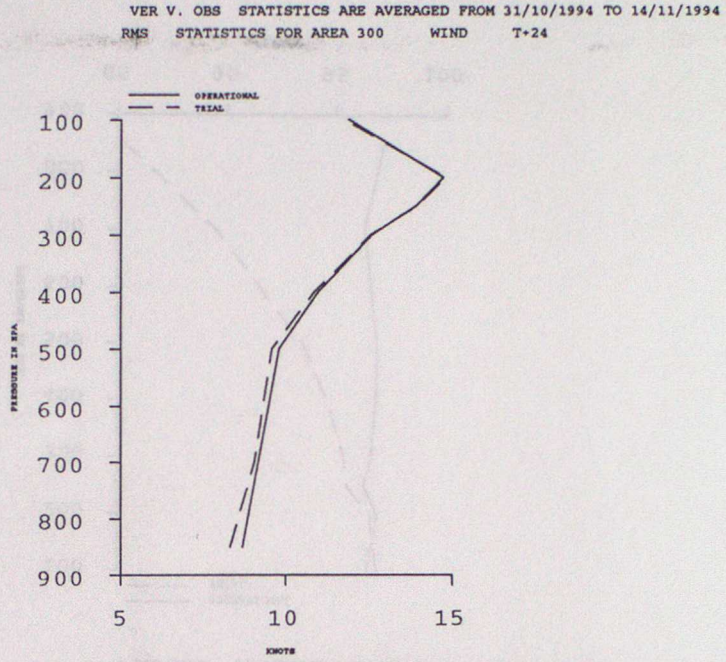
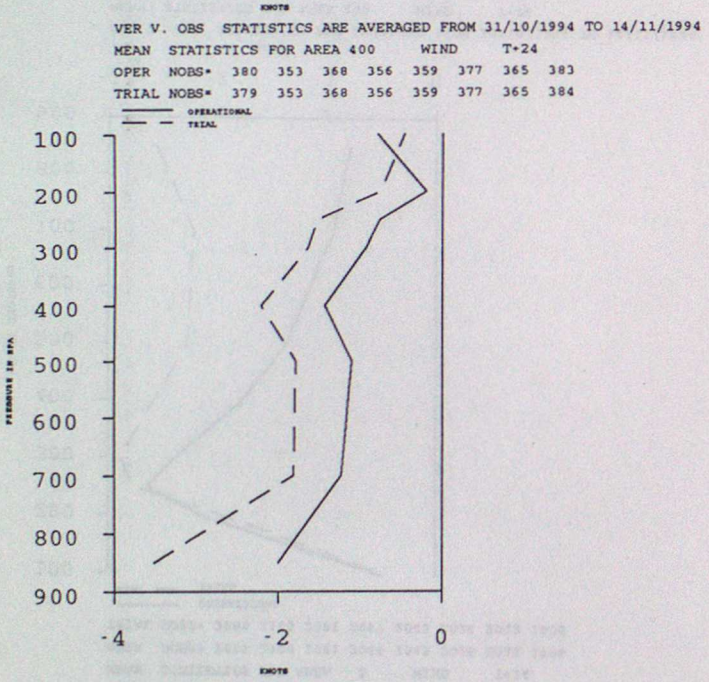


FIGURE 2.17


VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 300 WIND T+24
OPER NOBS= 2525 2276 2260 2295 2248 2171 2146 2037
TRIAL NOBS= 2527 2277 2260 2295 2249 2171 2147 2036
OPERATIONAL
TRIAL
100
200
300
400
500
600
700
800
900
PRESSURE IN HPA
-6
-4
-2
0
KNOTS


VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 300 WIND T+24
OPERATIONAL
TRIAL
100
200
300
400
500
600
700
800
900
PRESSURE IN HPA
5
10
15
KNOTS


VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
MEAN STATISTICS FOR AREA 400 WIND T+24
OPER NOBS= 380 353 368 356 359 377 365 383
TRIAL NOBS= 379 353 368 356 359 377 365 384
OPERATIONAL
TRIAL
100
200
300
400
500
600
700
800
900
PRESSURE IN HPA
-4
-2
0
KNOTS

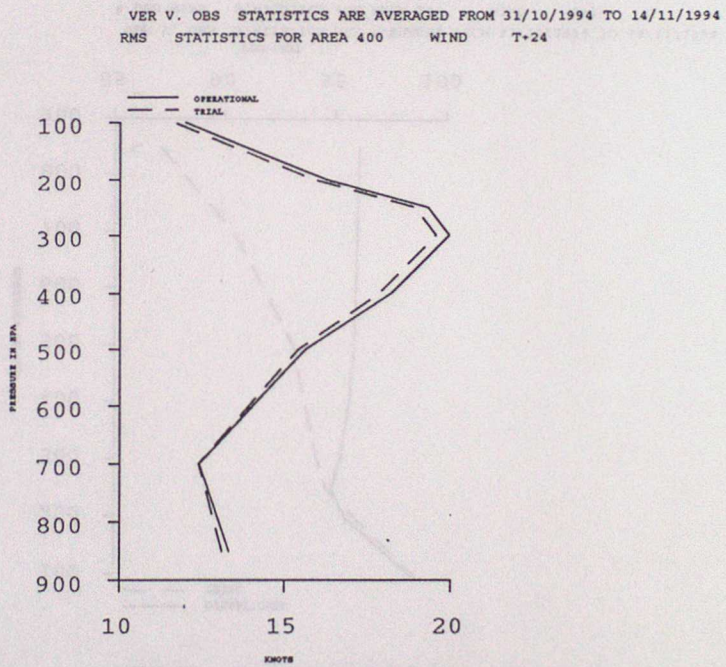
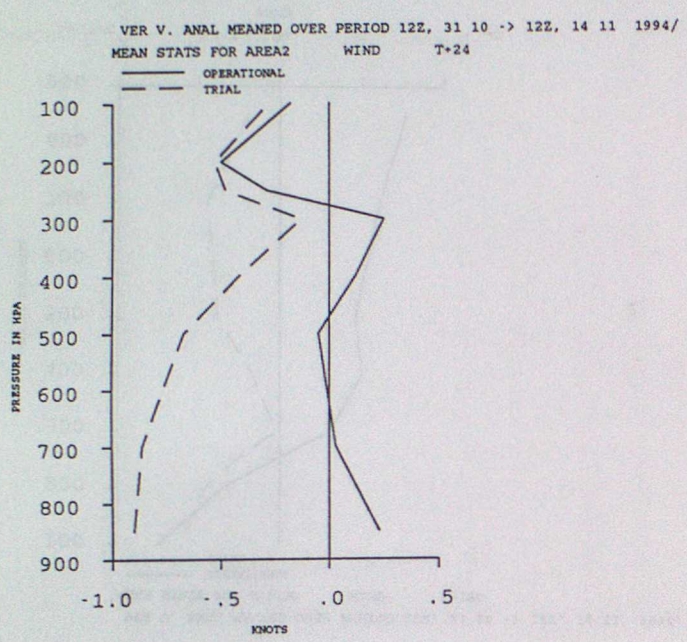
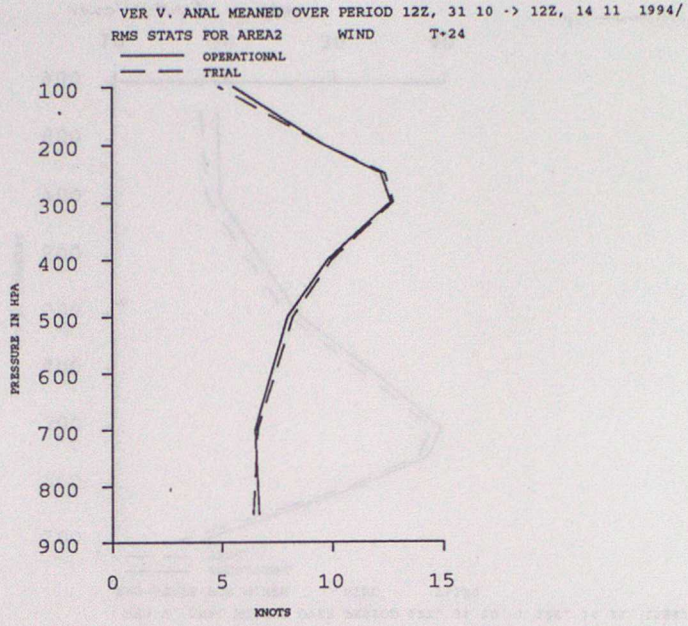
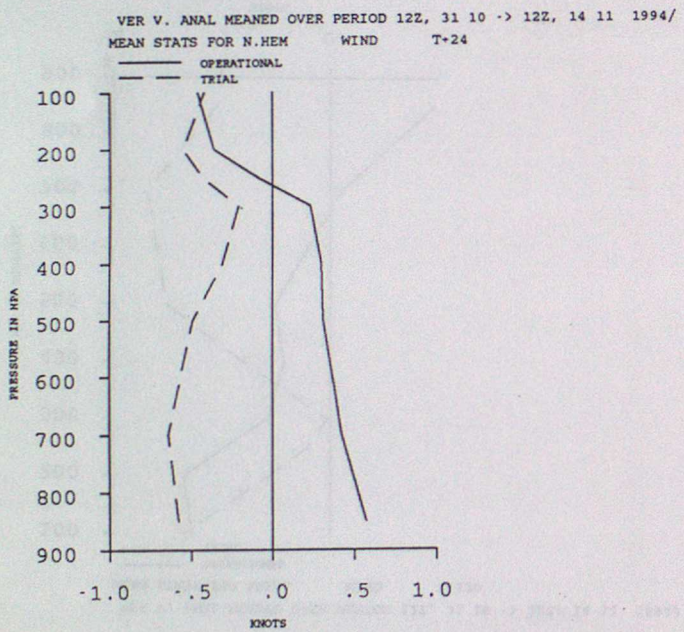

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
RMS STATISTICS FOR AREA 400 WIND T+24
OPERATIONAL
TRIAL
100
200
300
400
500
600
700
800
900
PRESSURE IN HPA
10
15
20
KNOTS

FIGURE 2.18


VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
MEAN STATS FOR AREA2 WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-1.0
-.5
.0
.5
KNOTS


VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
RMS STATS FOR AREA2 WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
0
5
10
15
KNOTS


VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
MEAN STATS FOR N.HEM WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-1.0
-.5
.0
.5
1.0
KNOTS

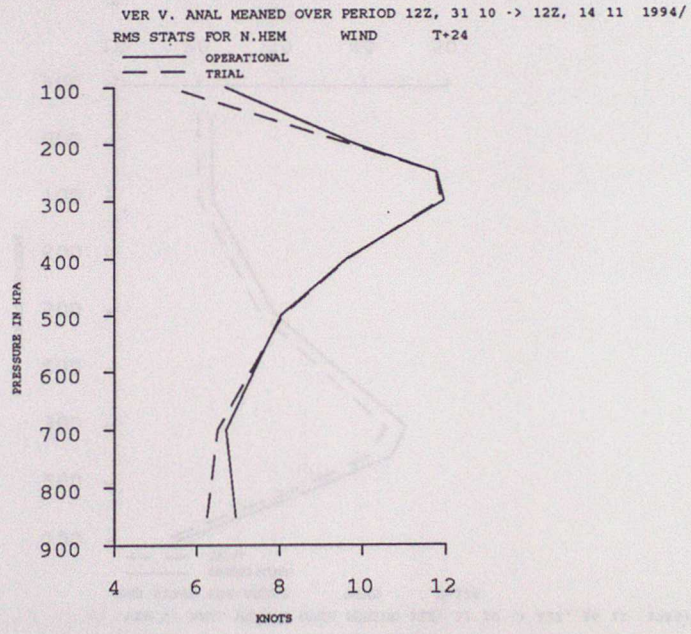

VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
RMS STATS FOR N.HEM WIND T+24
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
4
6
8
10
12
KNOTS

FIGURE 2.19

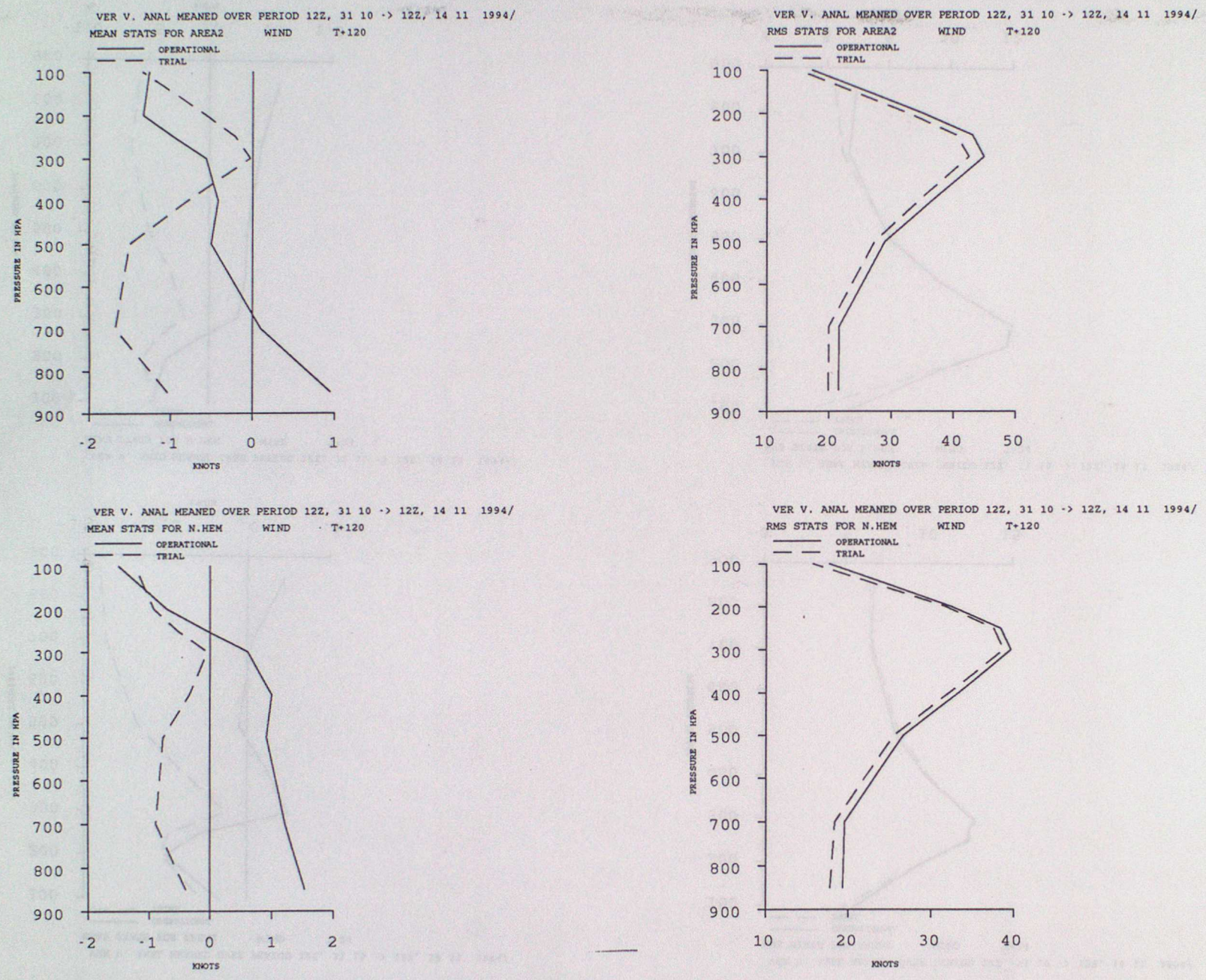

VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
MEAN STATS FOR AREA2 WIND T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-2
-1
0
1
KNOTS
VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
RMS STATS FOR AREA2 WIND T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
10
20
30
40
50
KNOTS
VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
MEAN STATS FOR N.HEM WIND T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
2
KNOTS
VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
RMS STATS FOR N.HEM WIND T+120
OPERATIONAL
TRIAL
PRESSURE IN HPA
KNOTS

FIGURE 2.20

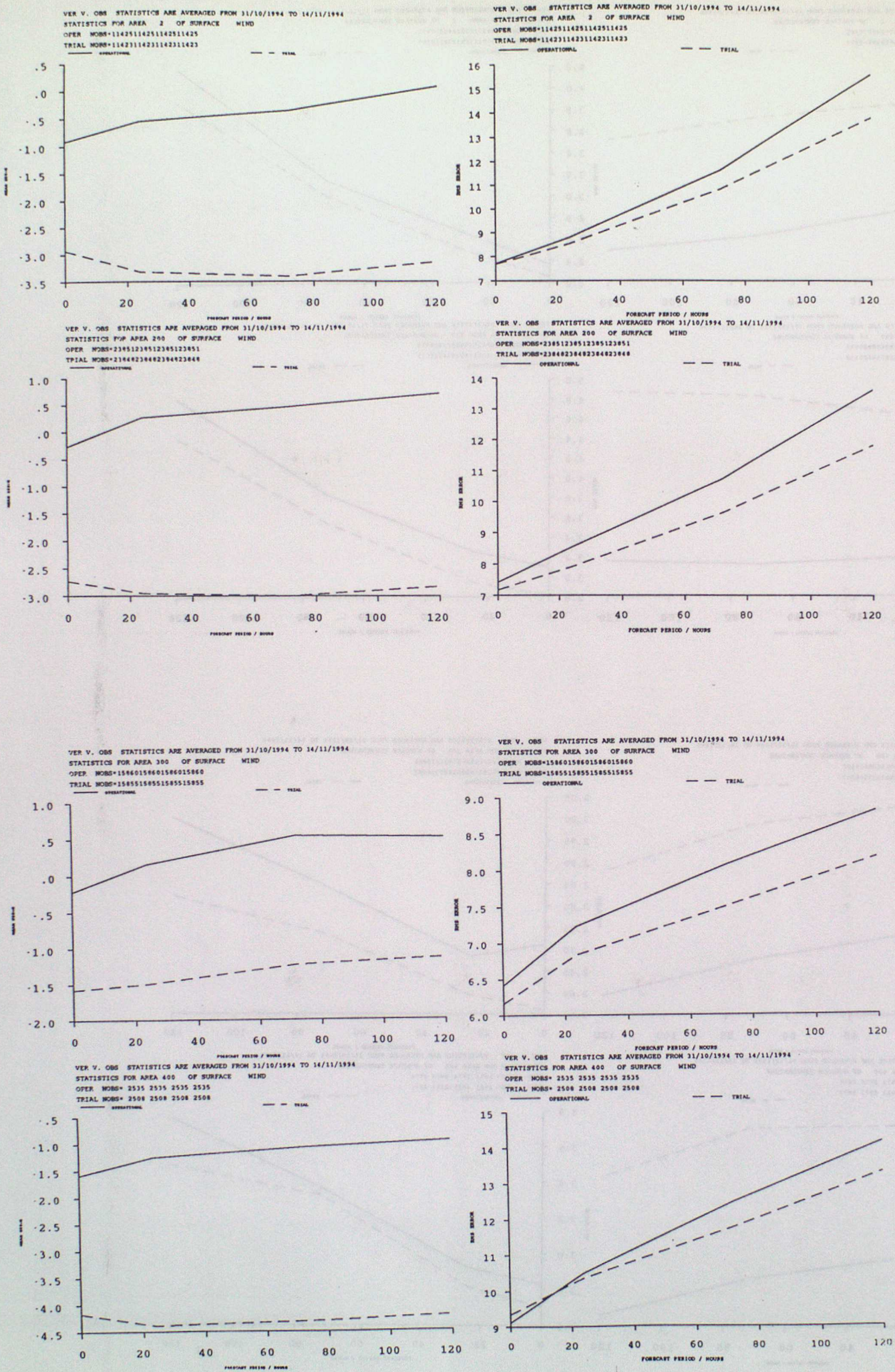
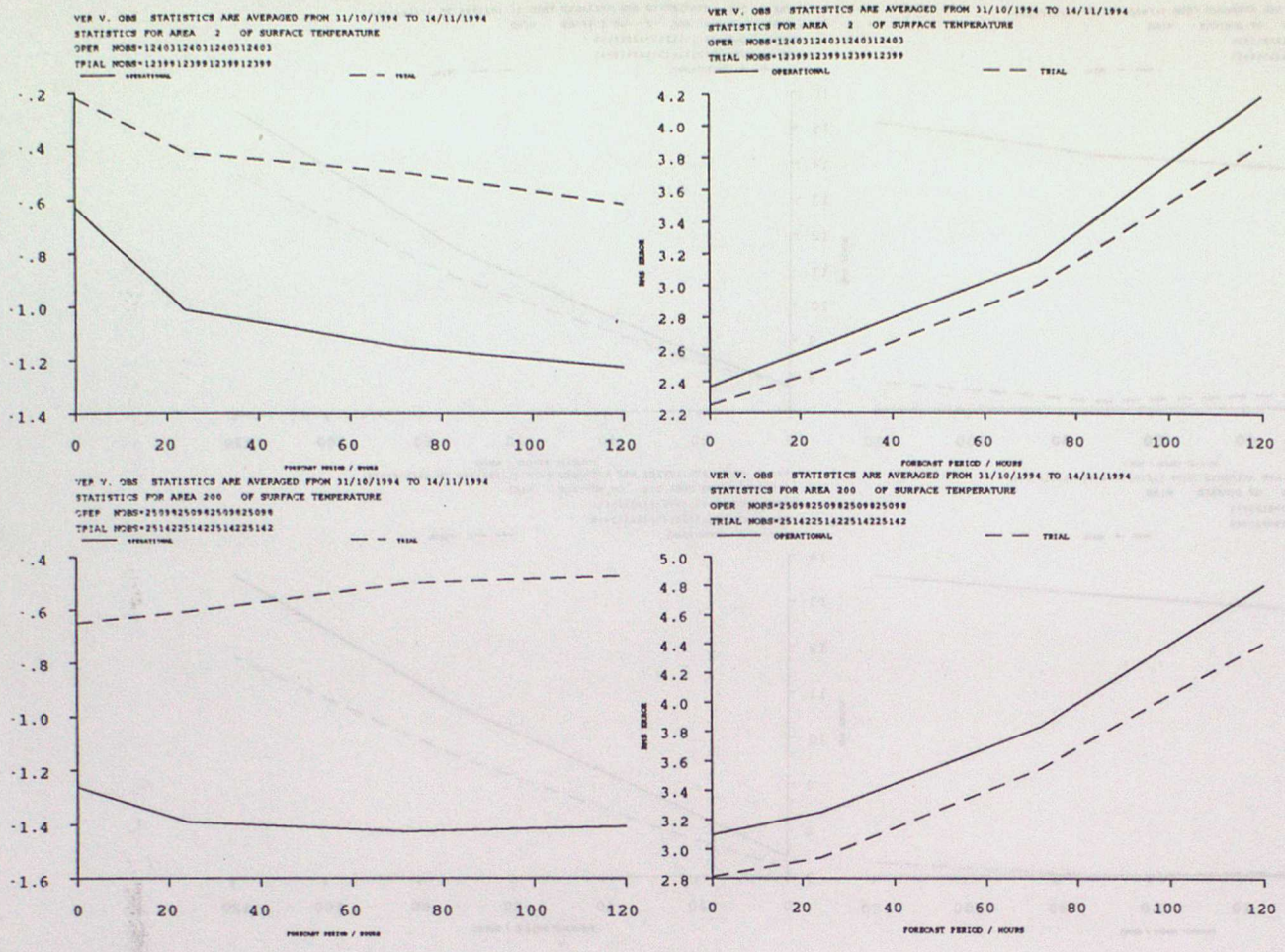

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 2 OF SURFACE WIND
OPER NOBS=1142511425114251142 5
TRIAL NOBS=1142311423114231142 3
OPERATIONAL
TRIAL
FORECAST PERIOD / HOURS
RMS ERROR
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 200 OF SURFACE WIND
OPER NOBS=2385123851238512385 1
TRIAL NOBS=2384823848238482384 8
OPERATIONAL
TRIAL
FORECAST PERIOD / HOURS
RMS ERROR
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 300 OF SURFACE WIND
OPER NOBS=1586015860158601586 0
TRIAL NOBS=1585515855158551585 5
OPERATIONAL
TRIAL
FORECAST PERIOD / HOURS
RMS ERROR
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 400 OF SURFACE WIND
OPER NOBS= 2535 2535 2535 2535
TRIAL NOBS= 2508 2508 2508 2508
OPERATIONAL
TRIAL
FORECAST PERIOD / HOURS
RMS ERROR

FIGURE 2.21


VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 2 OF SURFACE TEMPERATURE
OPER NOBS=1240312403124031240312403
TRIAL NOBS=1239912399123991239912399
OPERATIONAL
TRIAL
RMS ERROR
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 200 OF SURFACE TEMPERATURE
OPER NOBS=2509825098250982509825098
TRIAL NOBS=2514225142251422514225142
OPERATIONAL
TRIAL
RMS ERROR
FORECAST PERIOD / HOURS

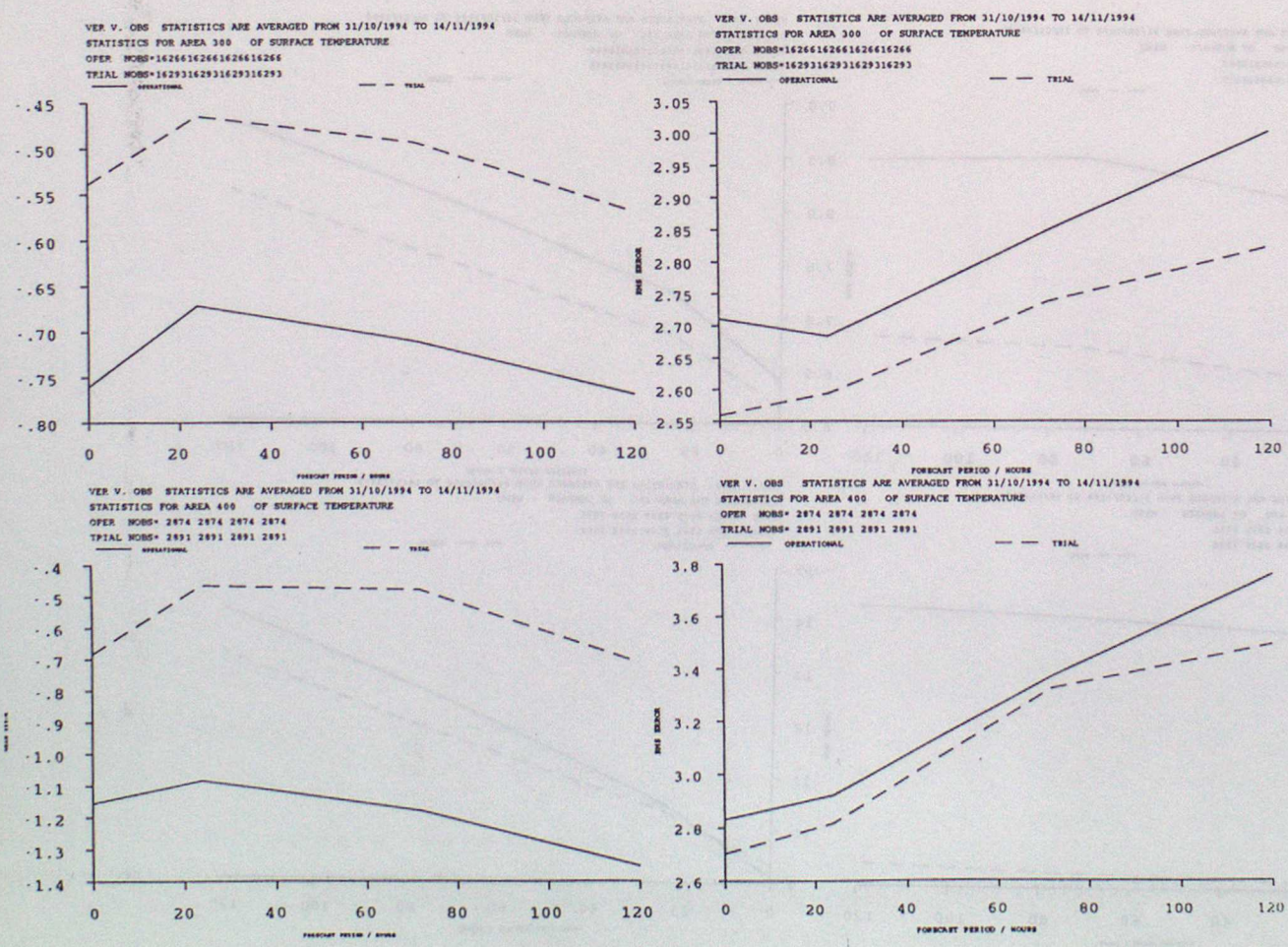
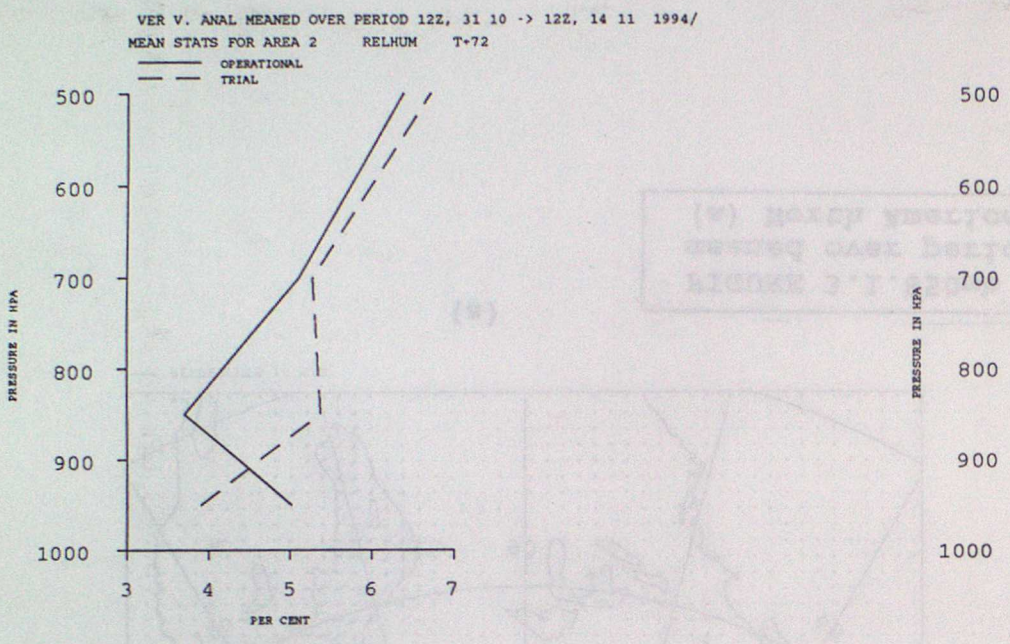
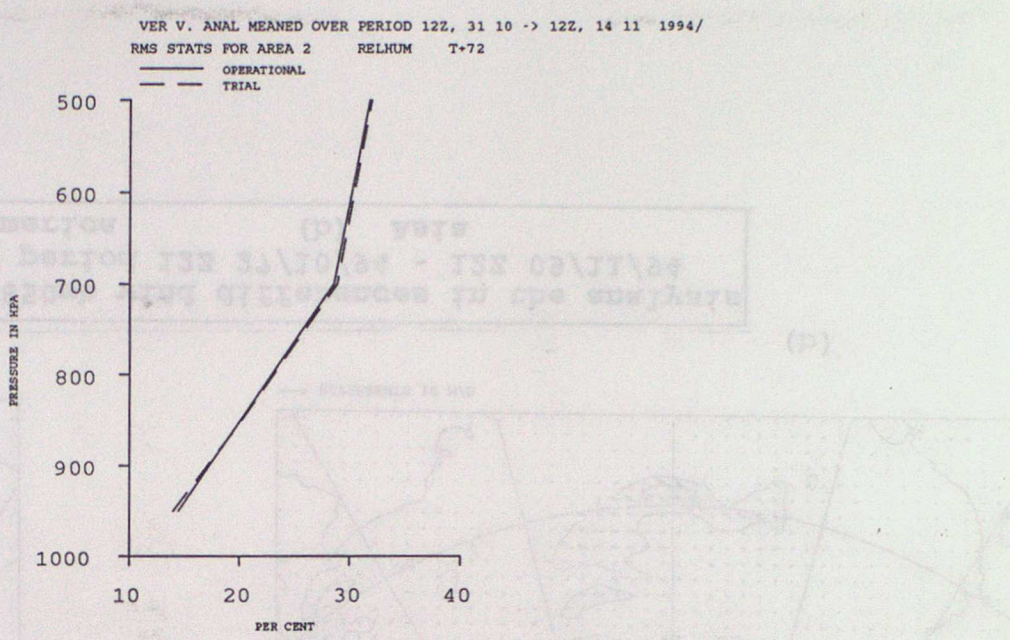
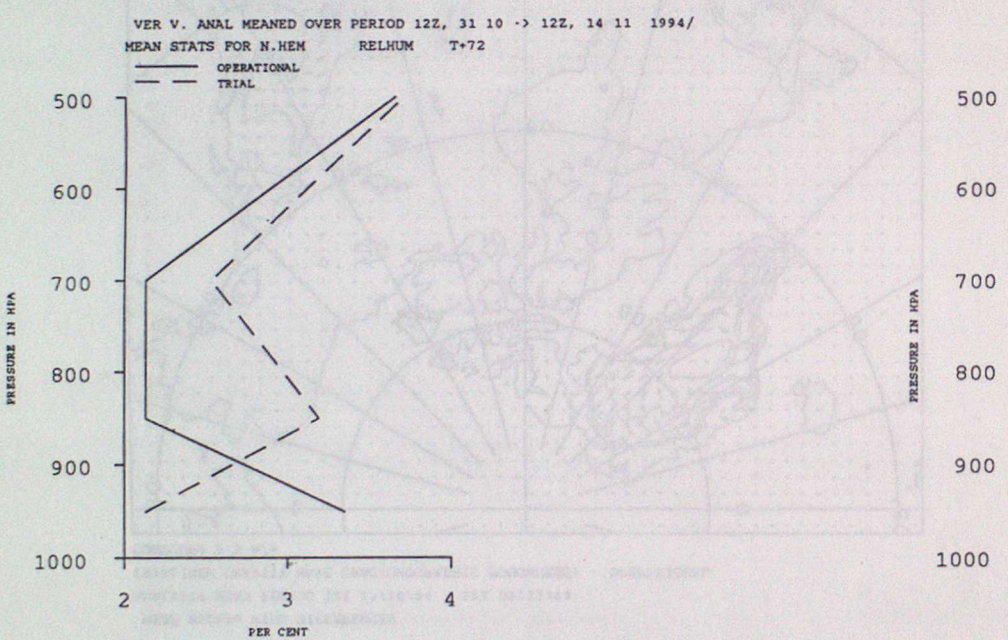

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 300 OF SURFACE TEMPERATURE
OPER NOBS=1626616266166266166266
TRIAL NOBS=1629316293162931629316293
OPERATIONAL
TRIAL
RMS ERROR
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 400 OF SURFACE TEMPERATURE
OPER NOBS= 2874 2874 2874 2874 2874
TRIAL NOBS= 2891 2891 2891 2891 2891
OPERATIONAL
TRIAL
RMS ERROR
FORECAST PERIOD / HOURS

FIGURE 2.22


VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
MEAN STATS FOR AREA 2 RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
500
600
700
800
900
1000
3
4
5
6
7
PER CENT


VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
RMS STATS FOR AREA 2 RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
500
600
700
800
900
1000
10
20
30
40
PER CENT


VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
MEAN STATS FOR N.HEM RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
500
600
700
800
900
1000
2
3
4
PER CENT

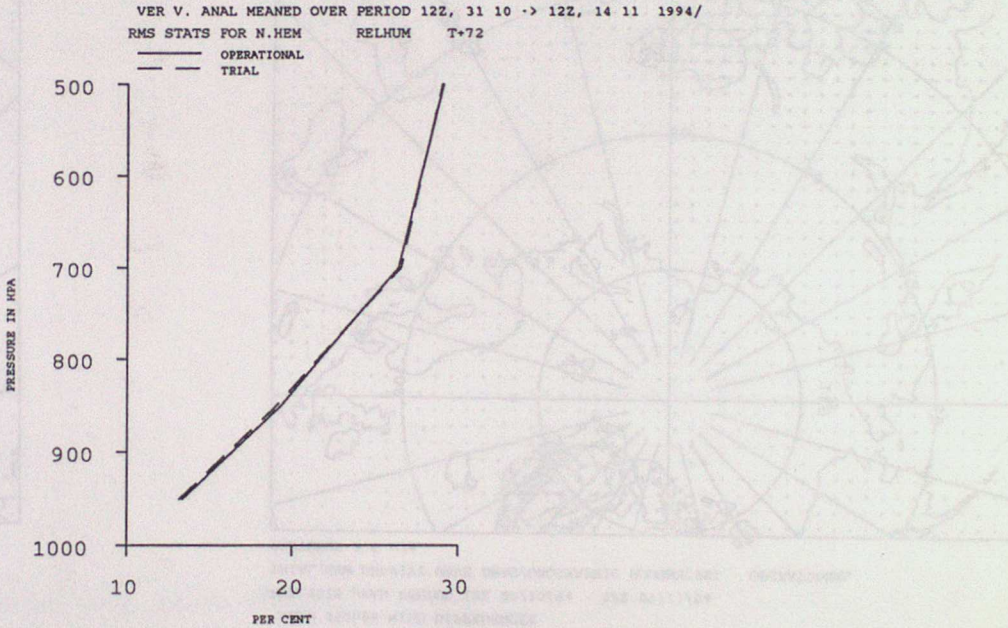

VER V. ANAL MEANED OVER PERIOD 12Z, 31 10 -> 12Z, 14 11 1994/
RMS STATS FOR N.HEM RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
500
600
700
800
900
1000
10
20
30
PER CENT

FIGURE 2.23

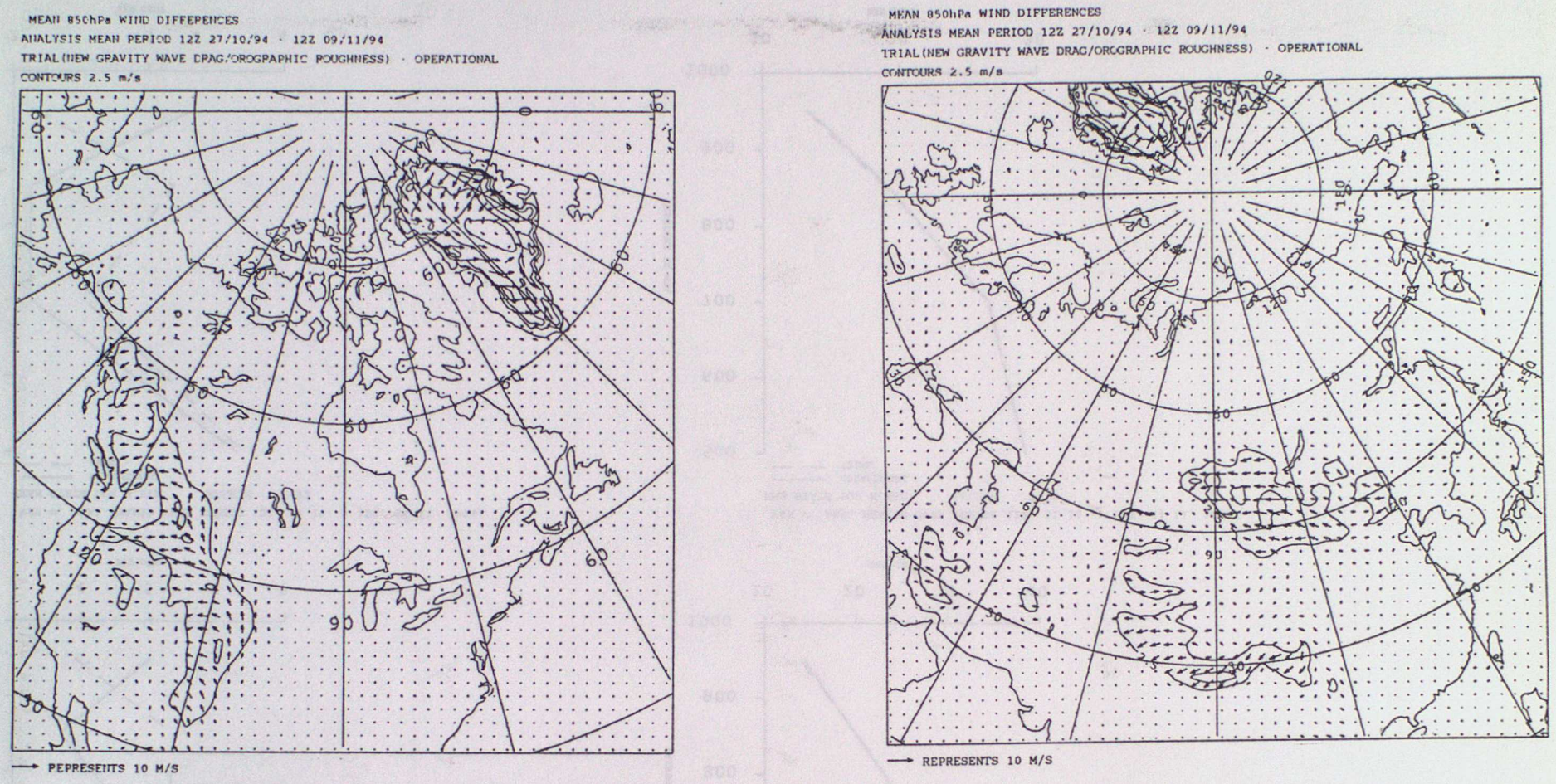
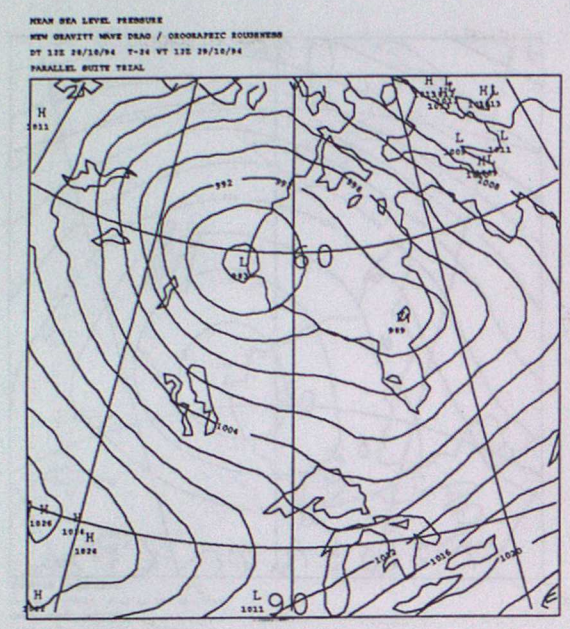
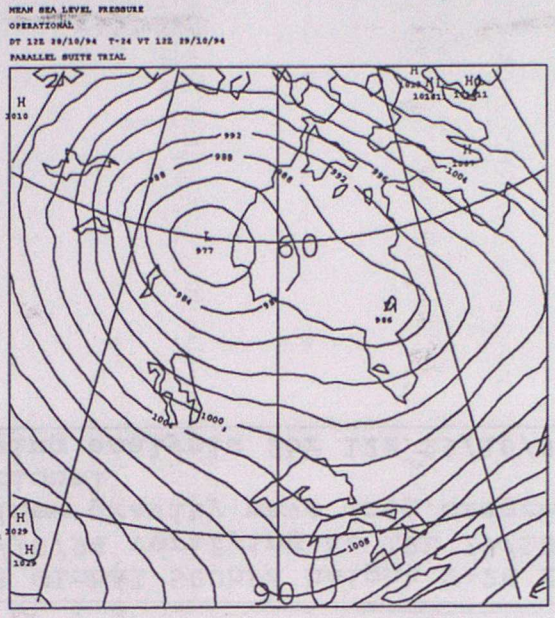


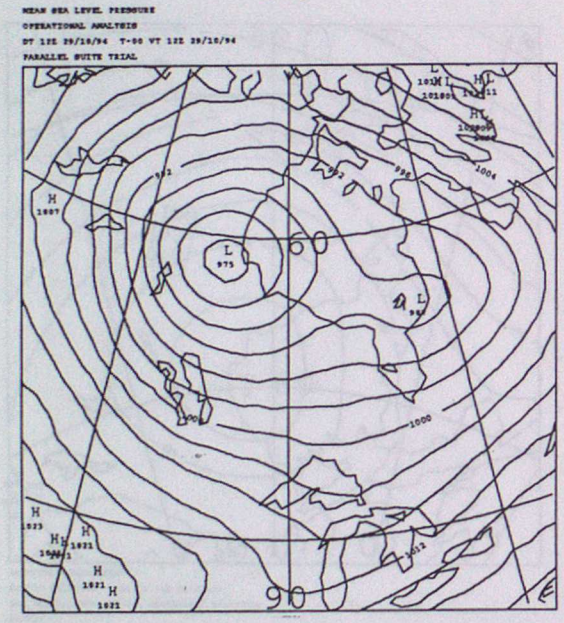
FIGURE 3.1.850mb wind differences in the analysis meaned over period 12Z 27/10/94 - 12Z 09/11/94
(a) North America (b) Asia



(a)

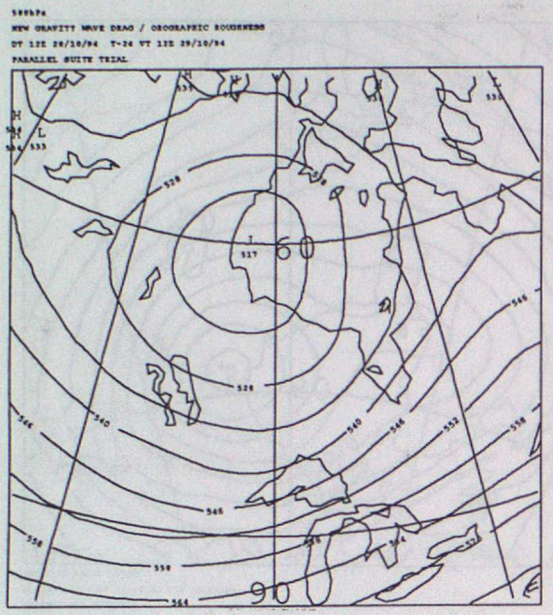


(b)

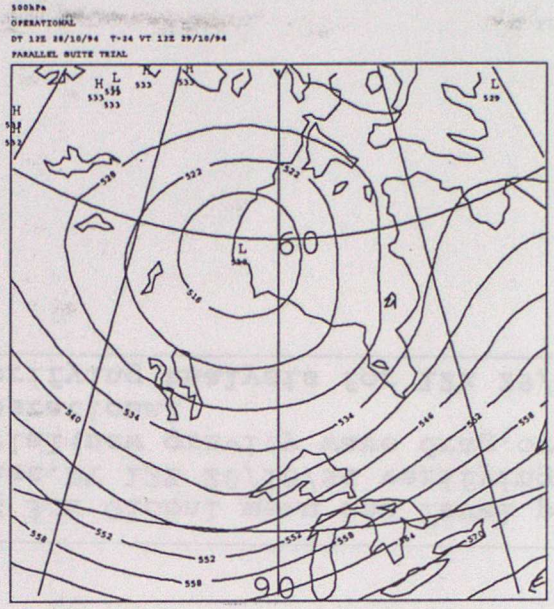


(c)

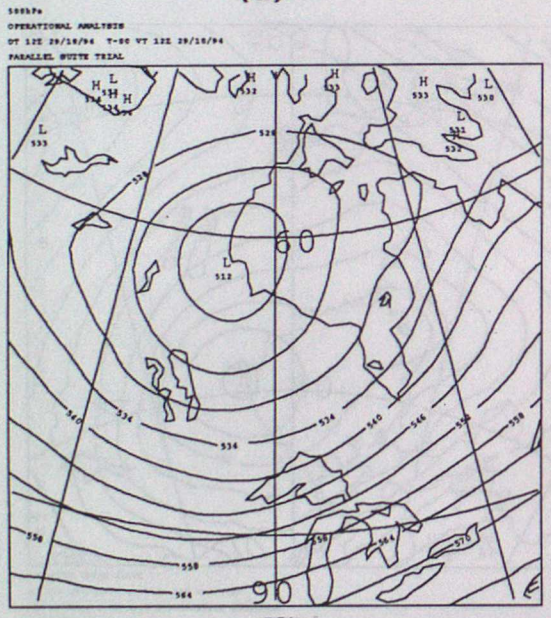
FIGURE 3.2 Global mean sea level pressure T+24 forecast.DT 12Z 28/10/94 verifying at 12Z 29/10/94
(a) Trial(new gravity wave drag.orographic roughness)
(b) Operational
(c) Verifying analysis for 12z 29/10/94



(a)



(b)



(c)

FIGURE 3.3 Global 500hPa height T+24 forecast.
DT 12Z 28/10/94 verifying at 12Z 29/10/94
(a) Trial(new gravity wave drag.orographic roughness)
(b) Operational
(c) Verifying analysis for 12z 29/10/94

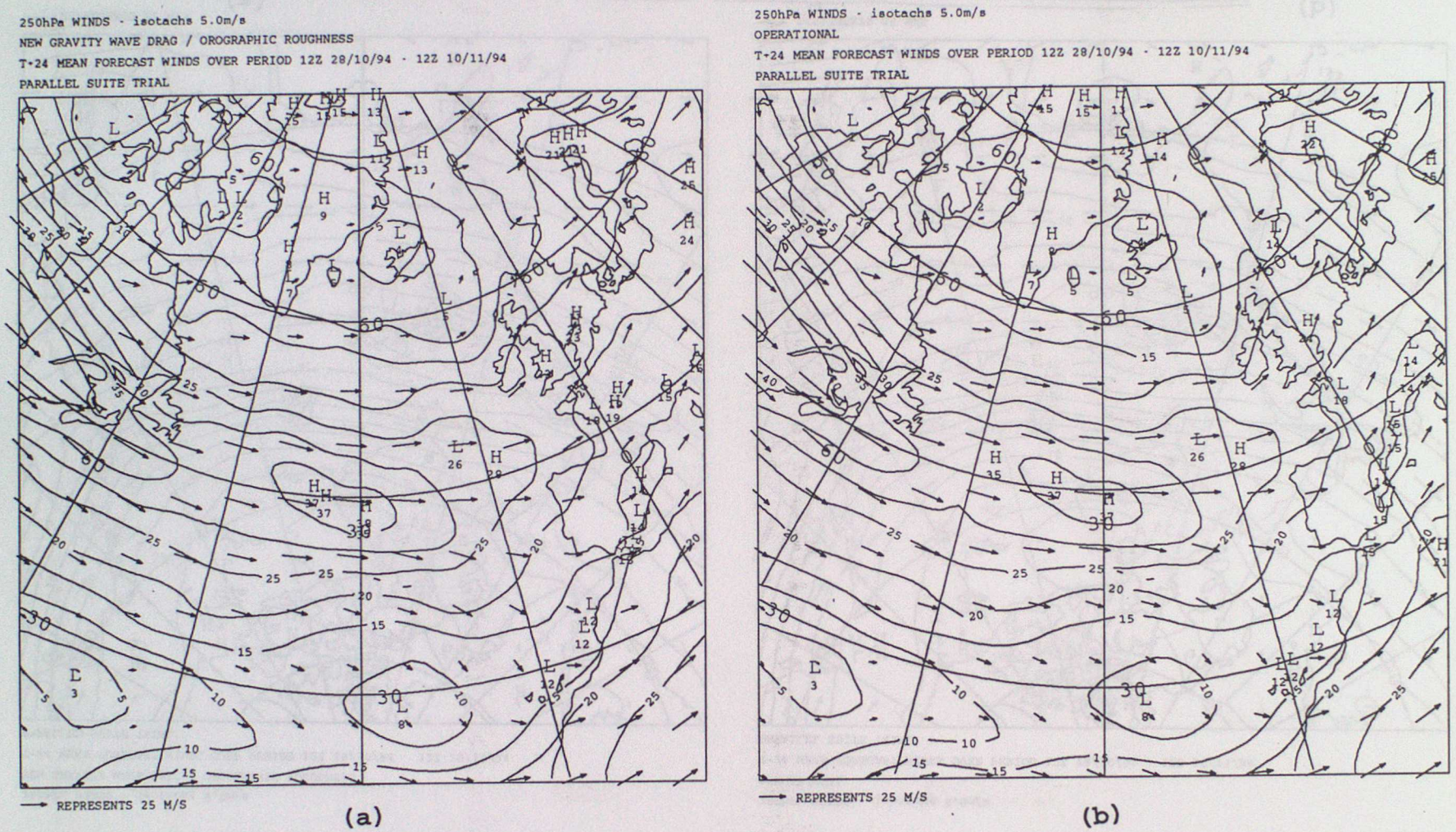


FIGURE 3.4 Global 250hPa wind T+24 forecast over the North Atlantic.
(forecast meaned over period 12Z 28/10/94 - 12Z 10/11/94)
(a) Trial(new gravity wave drag/orographic roughness)
(b) Operational

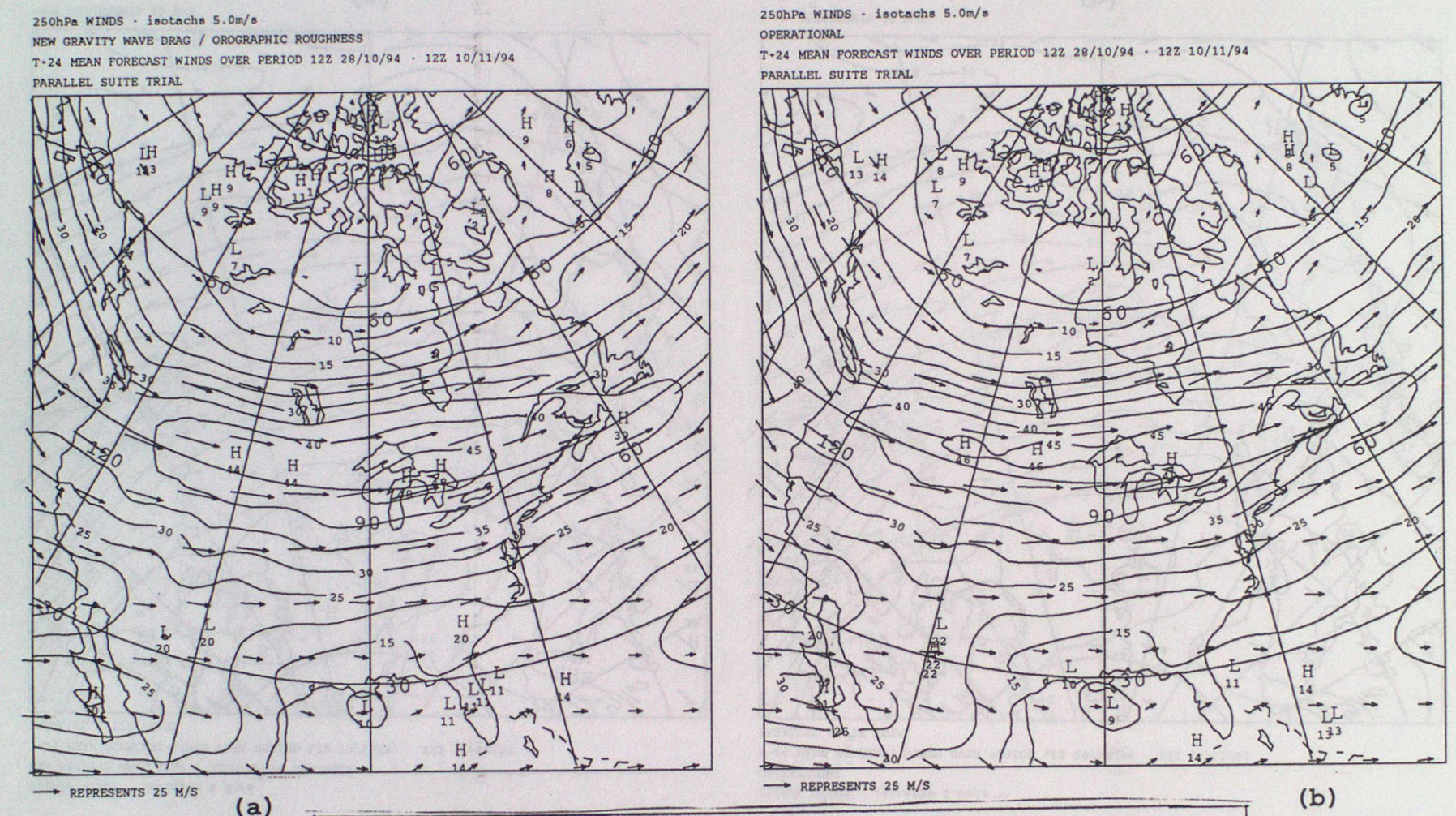
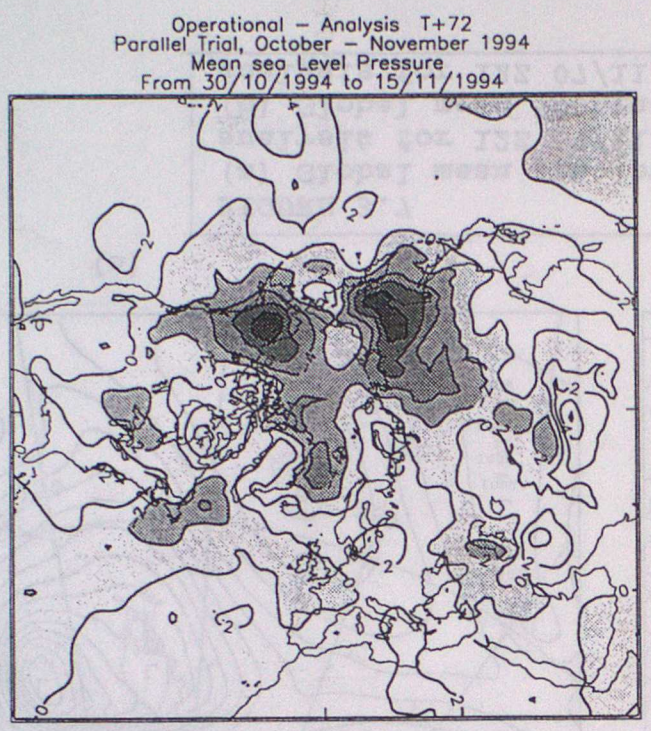
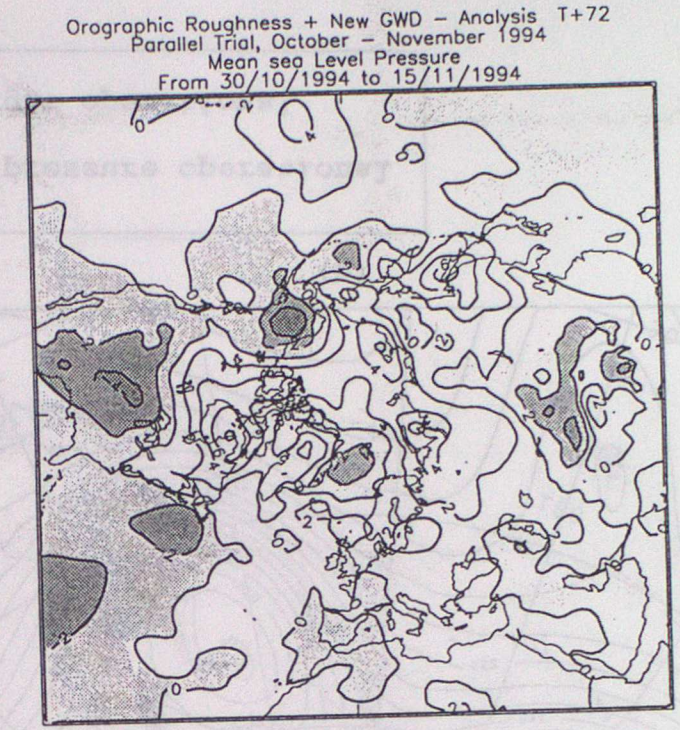


FIGURE 3.5 Global 250hPa wind T+24 forecast over North America.
(forecast meaned over period 12Z 28/10/94 - 12Z 10/11/94)
(a) Trial(new gravity wave drag/orographic roughness)
(b) Operational





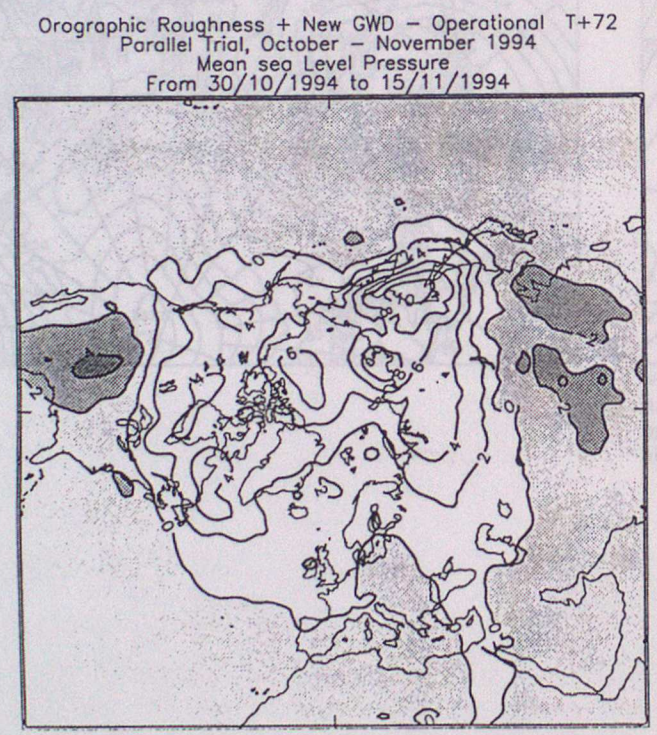
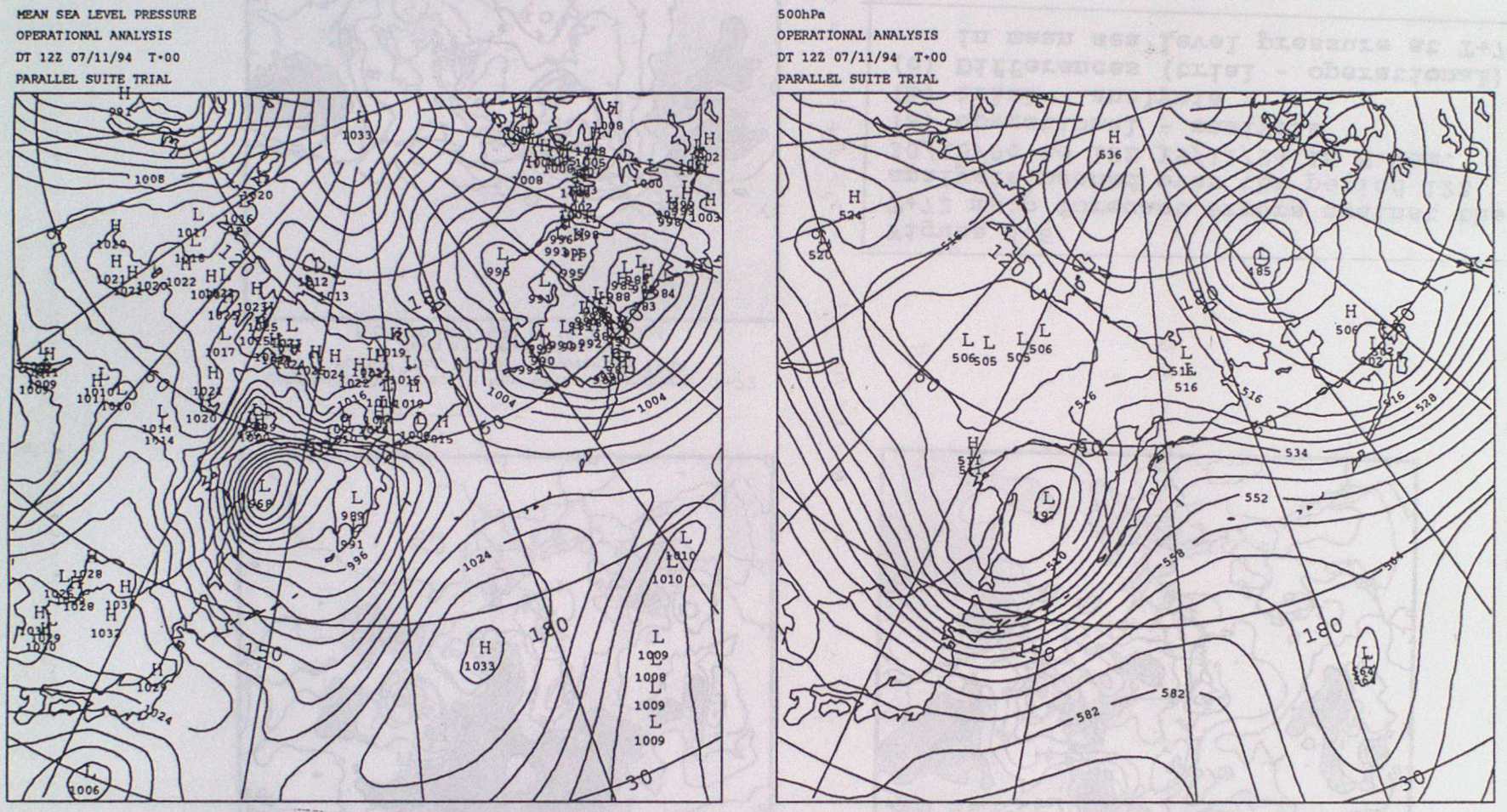


Figure 3.6
T+72 mslp forecast errors against the analysis meaned over the period 12Z 30/10/94 to 12Z 15/11/94 in N.Hem.
(a) operational - analysis
(b) trial - analysis
(c) Differences (trial - operational) in mean sea level pressure at T+72



(a) (b)

FIGURE 3.7
(a) Global mean sea level pressure operational analysis for 12Z 07/11/94
(b) Global mean 500hPa height operational analysis for 12Z 07/11/94

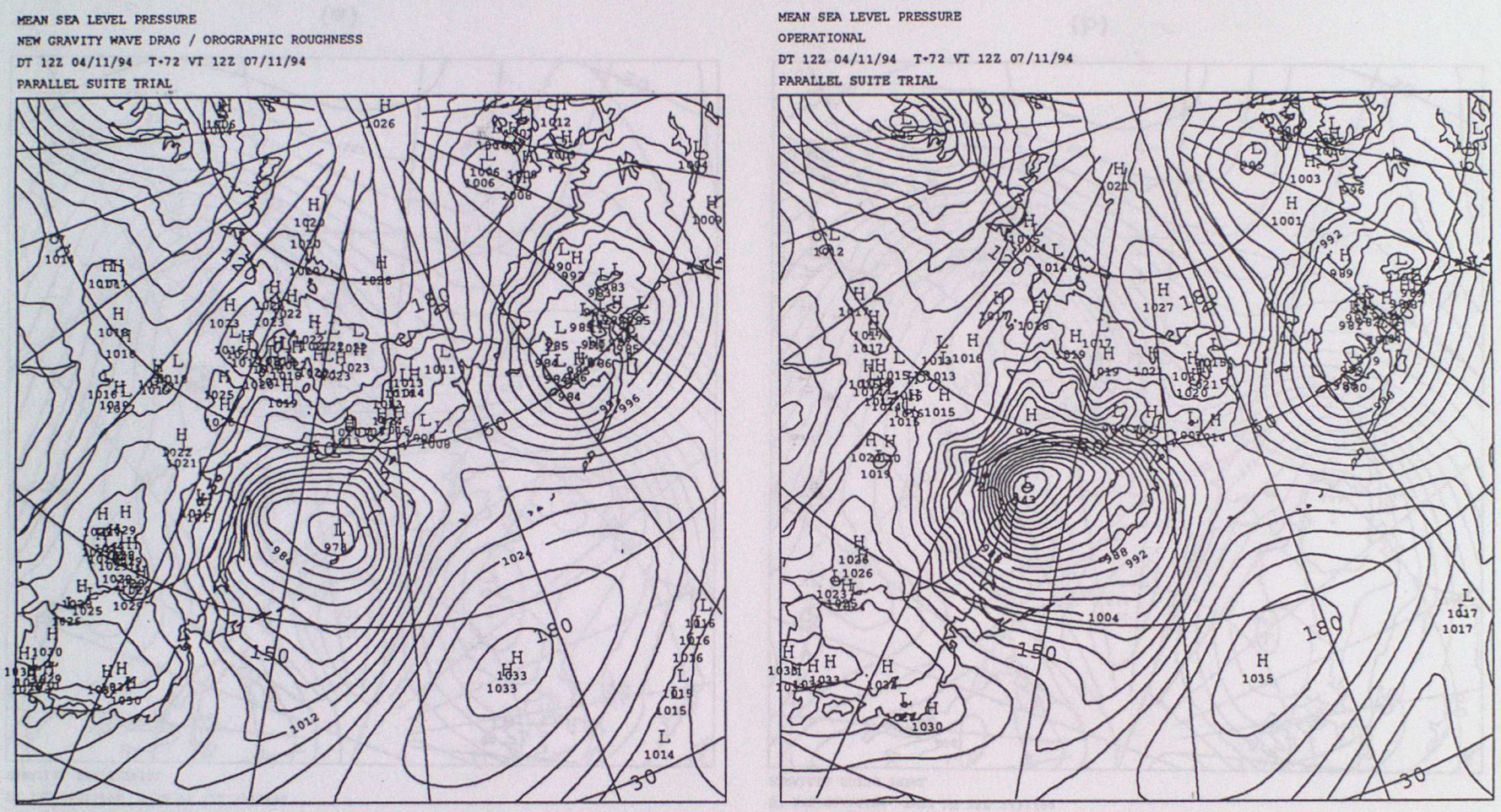


FIGURE 3.8 Global mean sea level pressure T+72 forecast DT12Z 04/11/94 verifying 12Z 07/11/94
(a) Trial(new gravity wave drag/orographic roughness)
(b) Operational

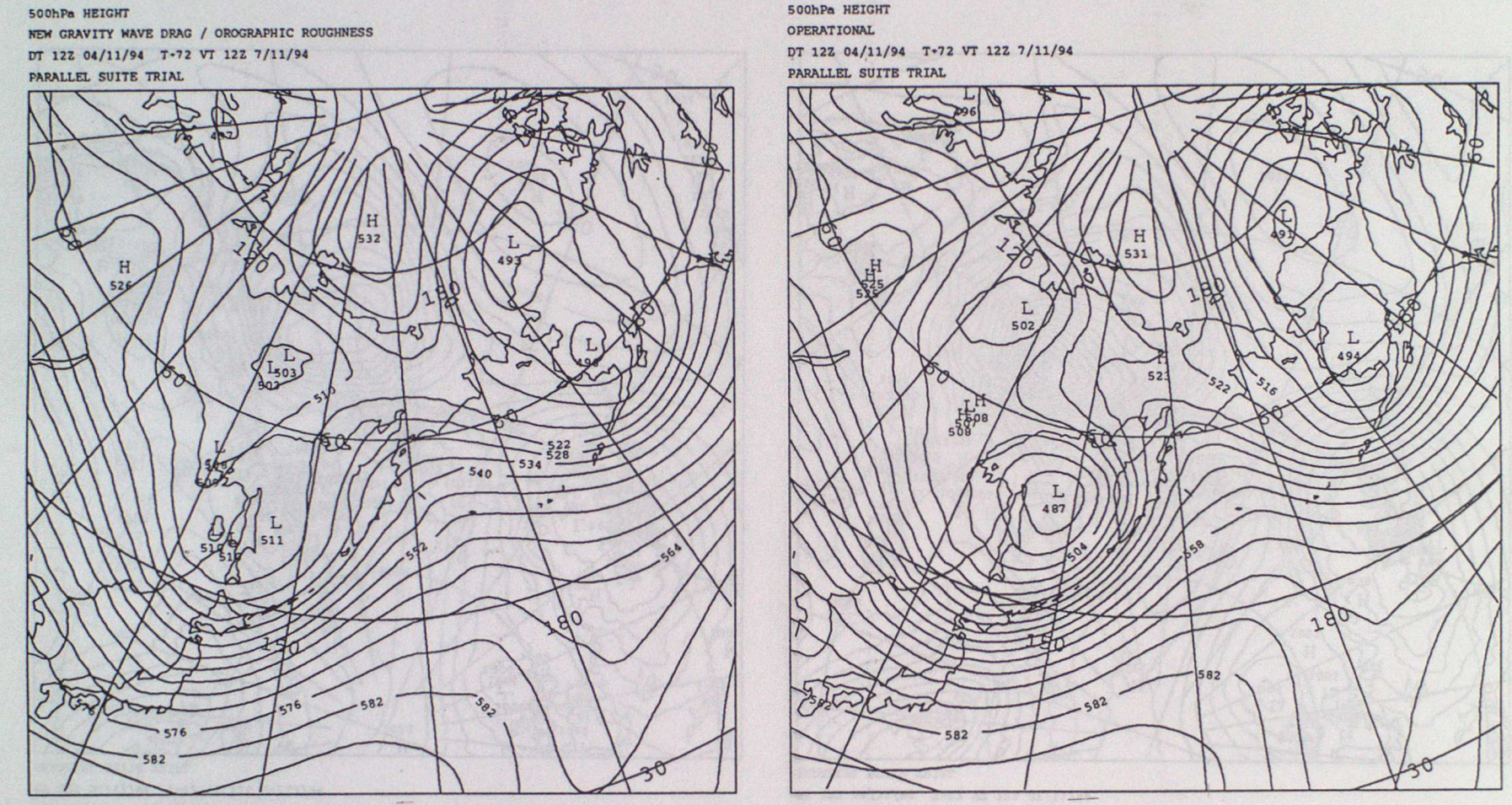


FIGURE 3.9 Global 500hPa height T+72 forecast
DT12Z 04/11/94 verifying 12Z 07/11/94
(a) Trial(new gravity wave drag/orographic roughness)
(b) Operational

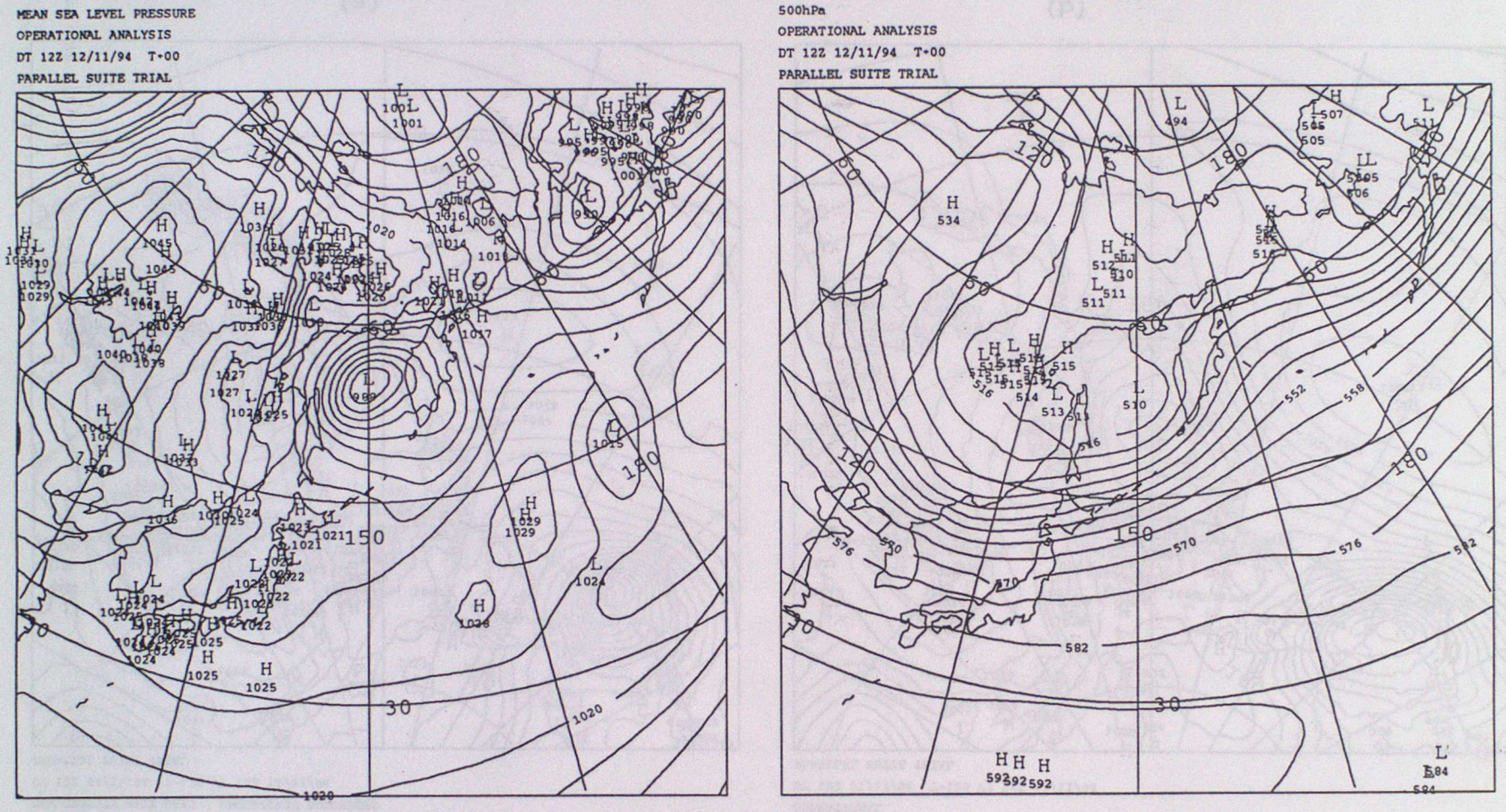


FIGURE 3.10
(a) Global mean sea level pressure operational analysis for 12Z 12/11/94
(b) Global 500hPa height operational analysis for 12Z 12/11/94

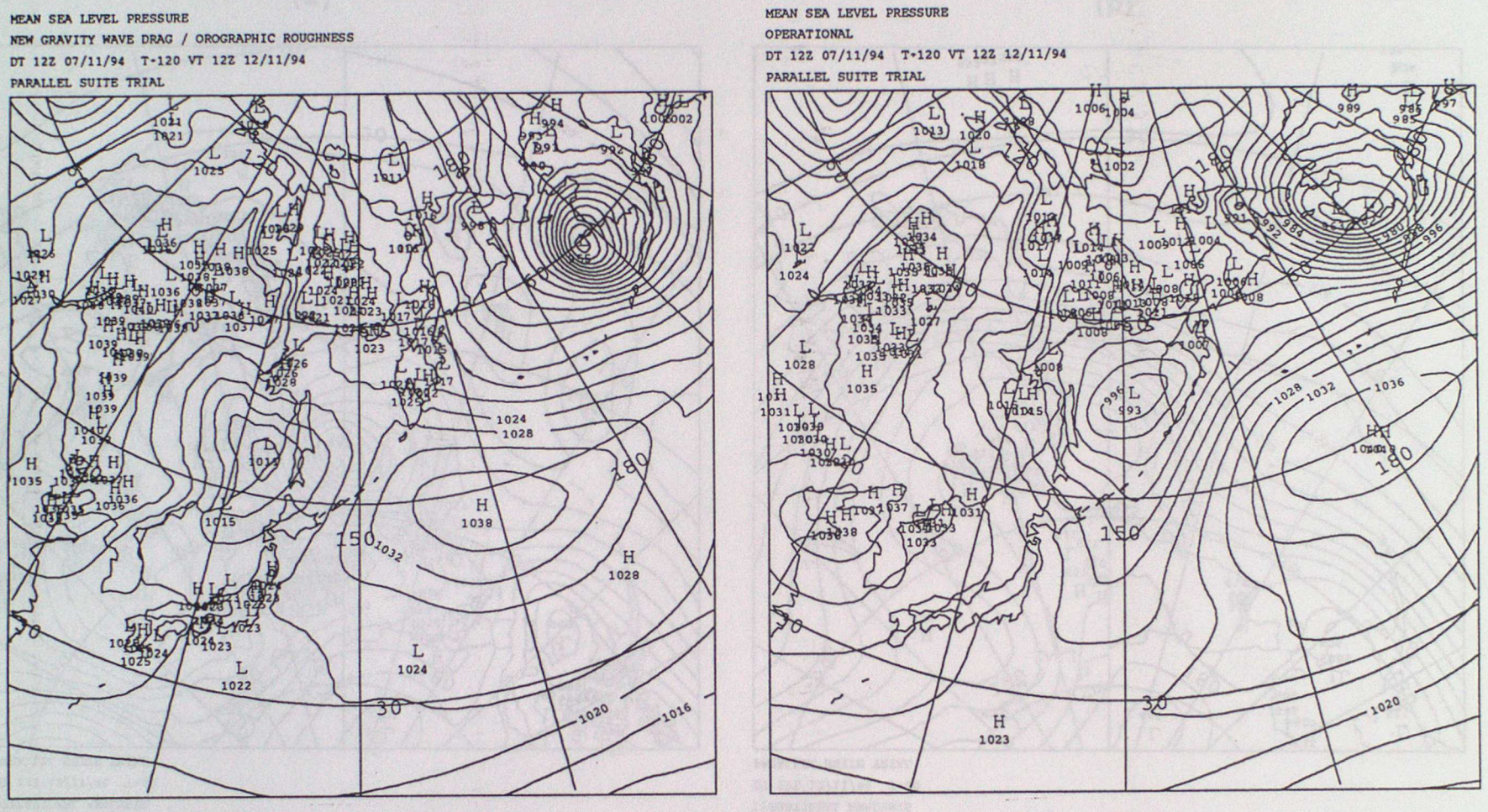


FIGURE 3.11 Global mean sea level pressure T+120 forecast DT12Z 07/11/94 verifying at 12Z 12/11/94
(a) Trial(new gravity wave drag/orographic roughness)
(b) Operational

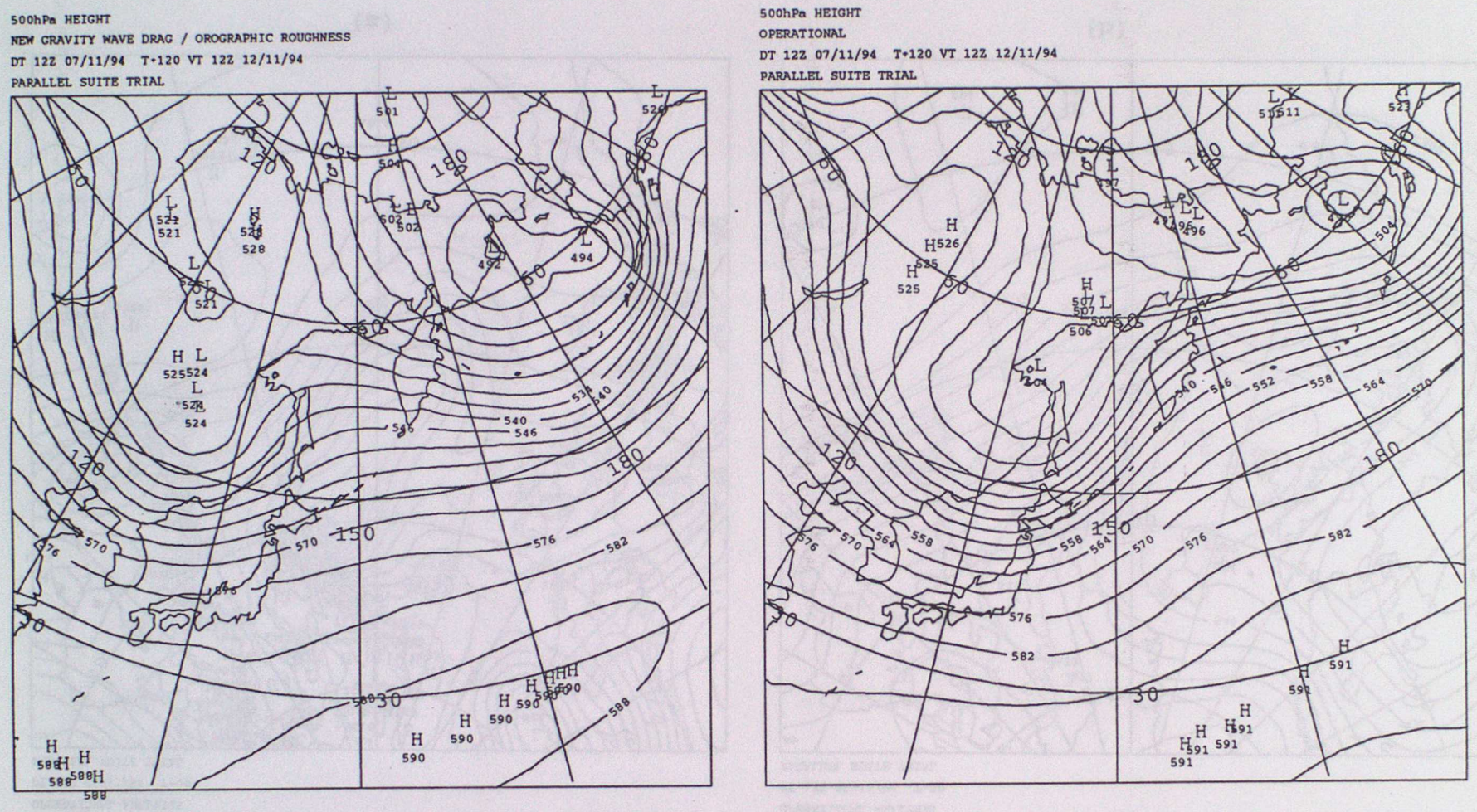


FIGURE 3.12 Global 500hPa height T+120 forecast
DT12Z 07/11/94 verifying 12Z 12/11/94
(a) Trial(new gravity wave drag/orographic roughness)
(b) Operational

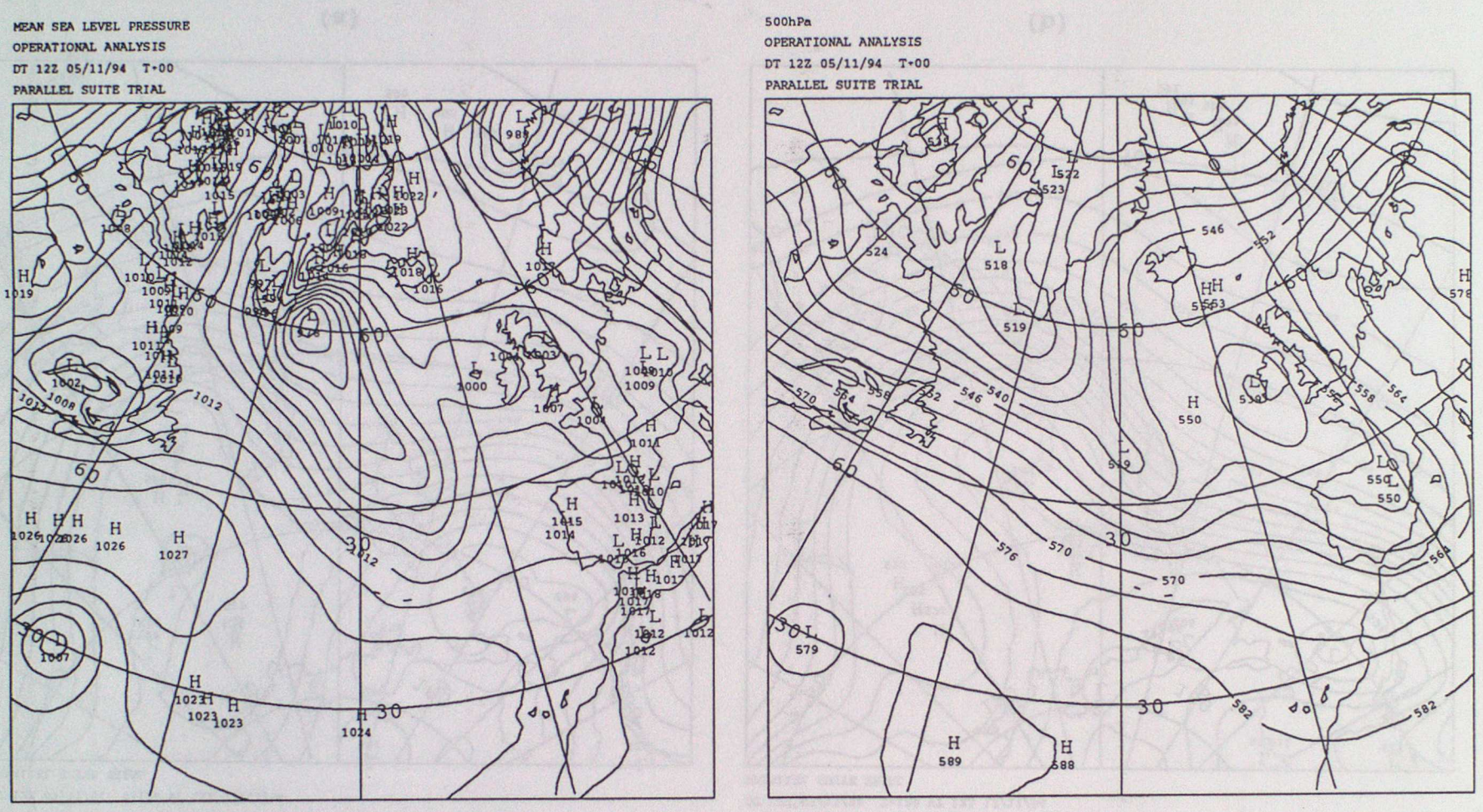


FIGURE 3.13
(a) Global mean sea level pressure operational analysis for 12Z 05/11/94
(b) Global 500hPa height operational analysis for 12Z 05/11/94

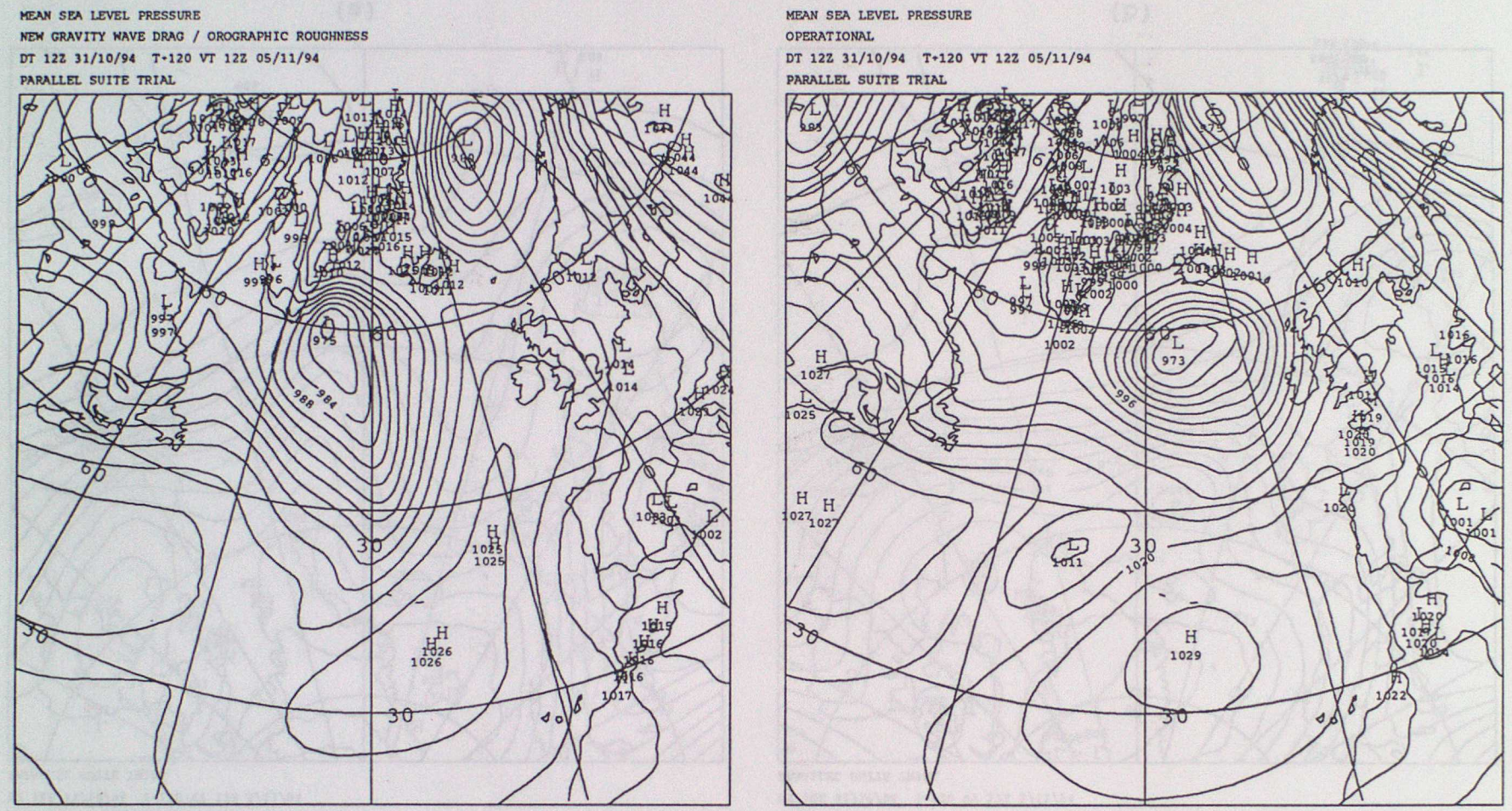


FIGURE 3.14 Global mean sea level pressure T+120 forecast DT12Z 31/10/94 verifying at 12Z 05/11/94
(a) Trial(new gravity wave drag/orographic roughness)
(b) Operational

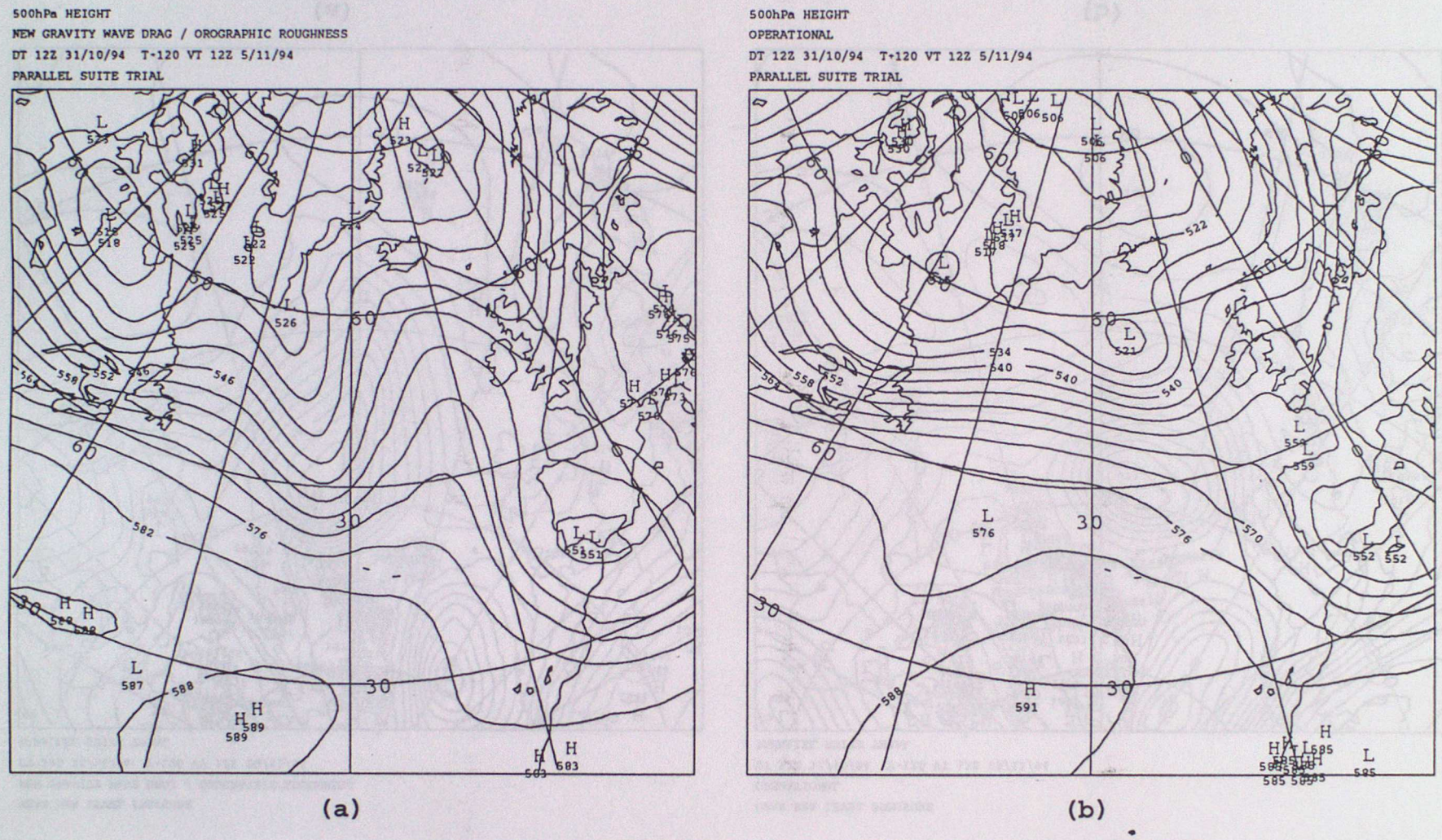


FIGURE 3.15 Global 500hPa height T+120 forecast
DT12Z 31/10/94 verifying 12Z 05/11/94
(a) Trial(new gravity wave drag/orographic roughness)
(b) Operational

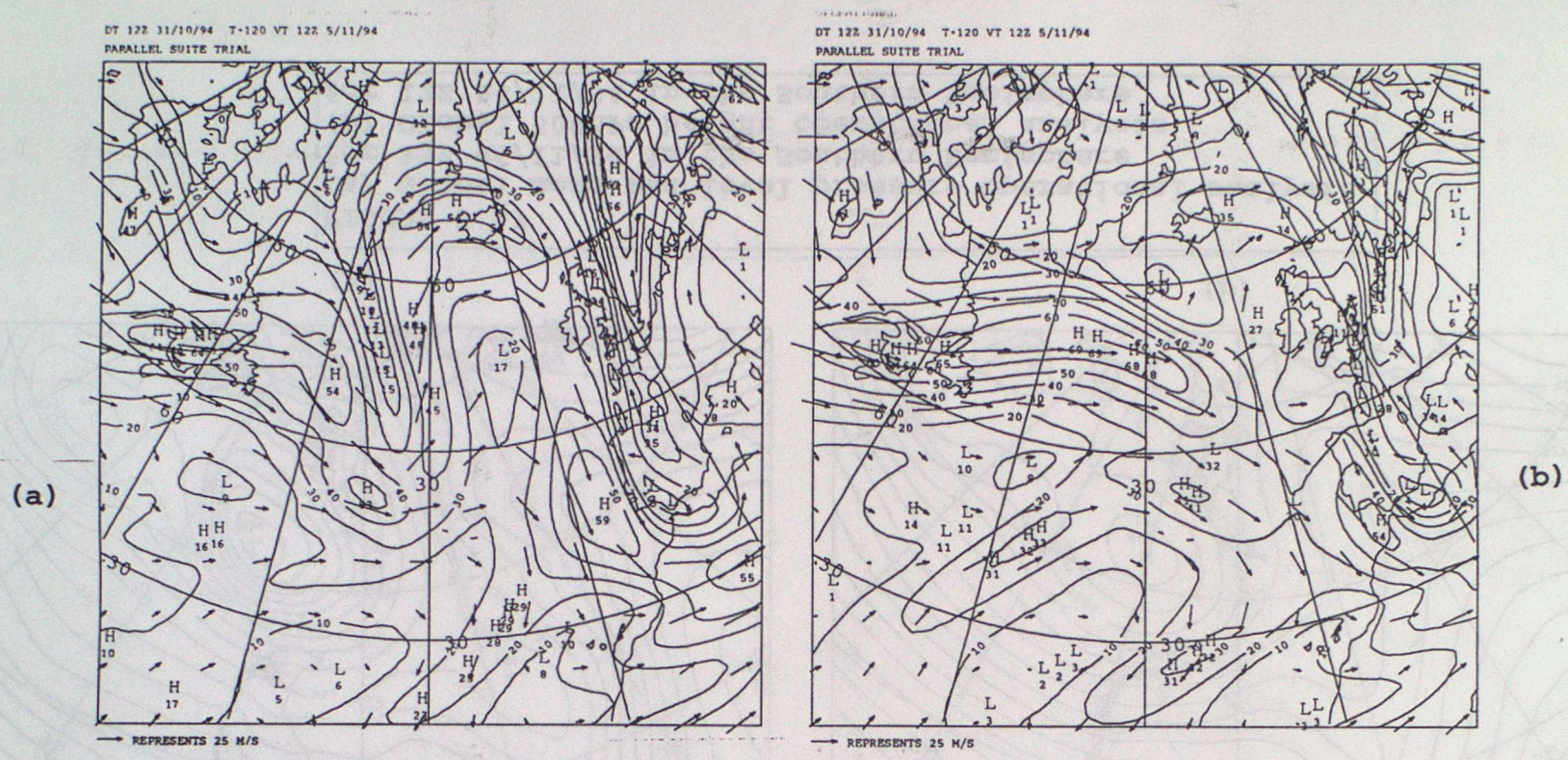


FIGURE 3.16
(a) Global 250hPa winds T+120 forecast DT12Z 31/10/94 verifying at 12Z 05/11/94 from trial (new gravity wave drag/orographic roughness)

(b) Global 250hPa winds T+120 forecast DT12Z 31/10/94 verifying at 12Z 05/11/94 from operational

(c) Global 250hPa winds operational analysis for 12Z 05/11/94

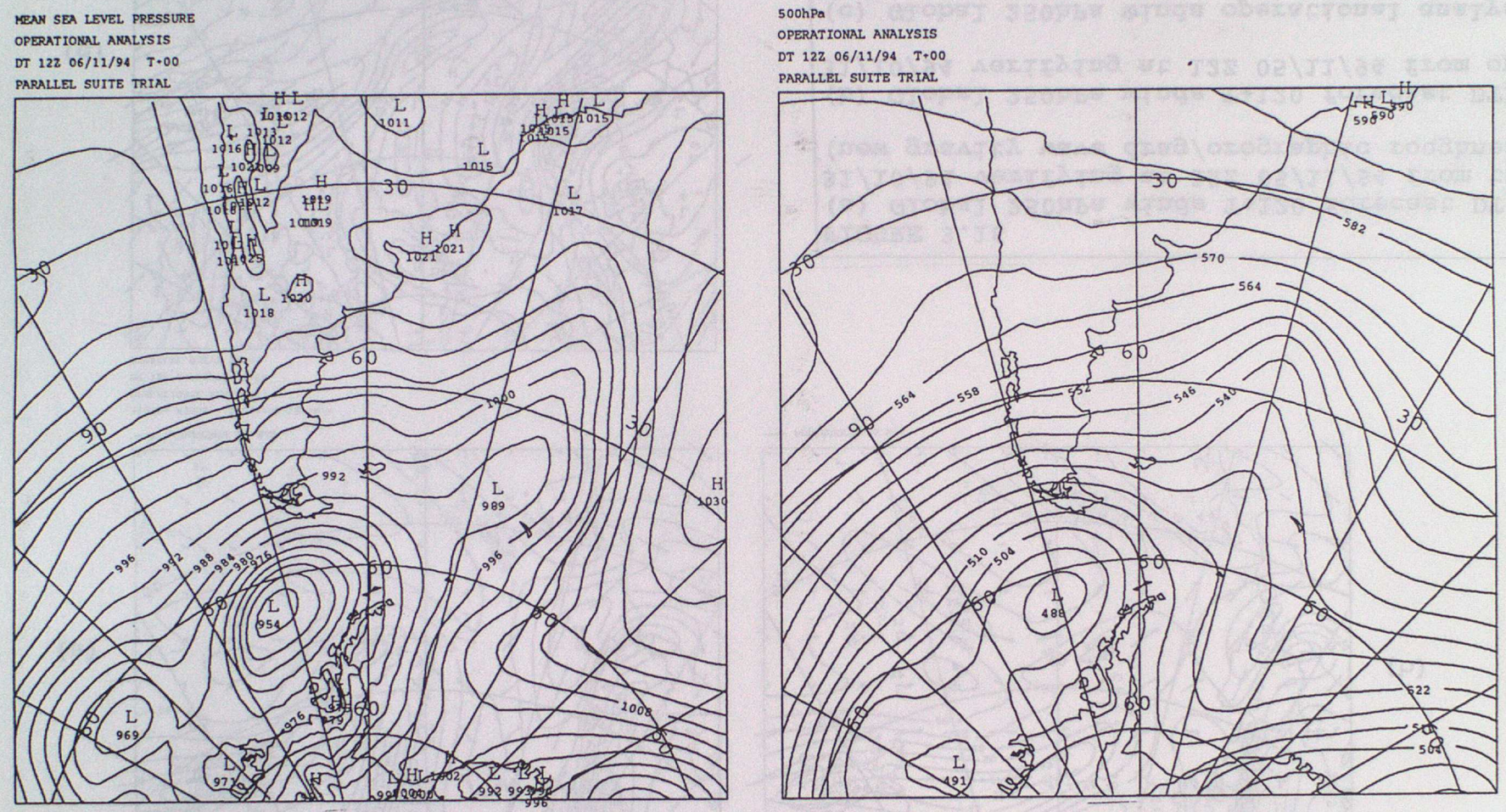
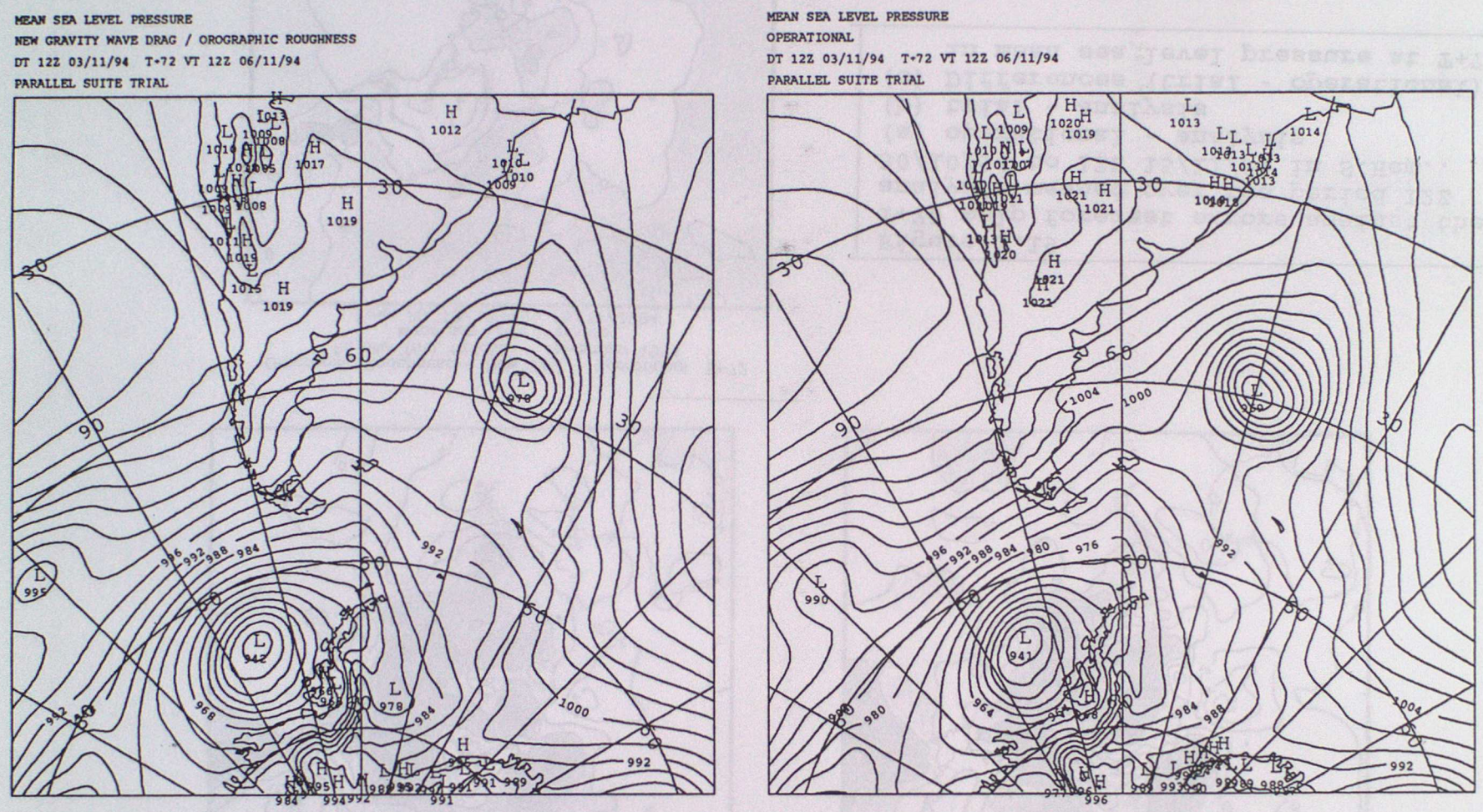
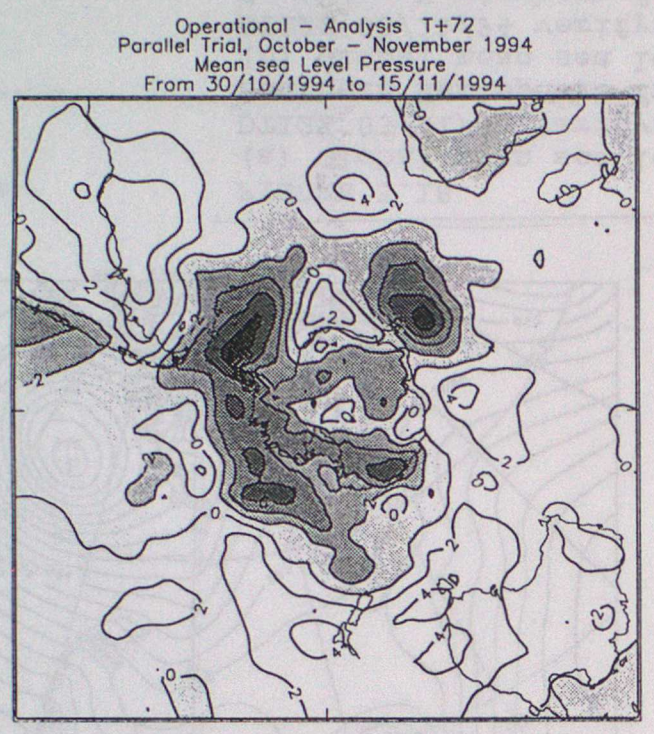


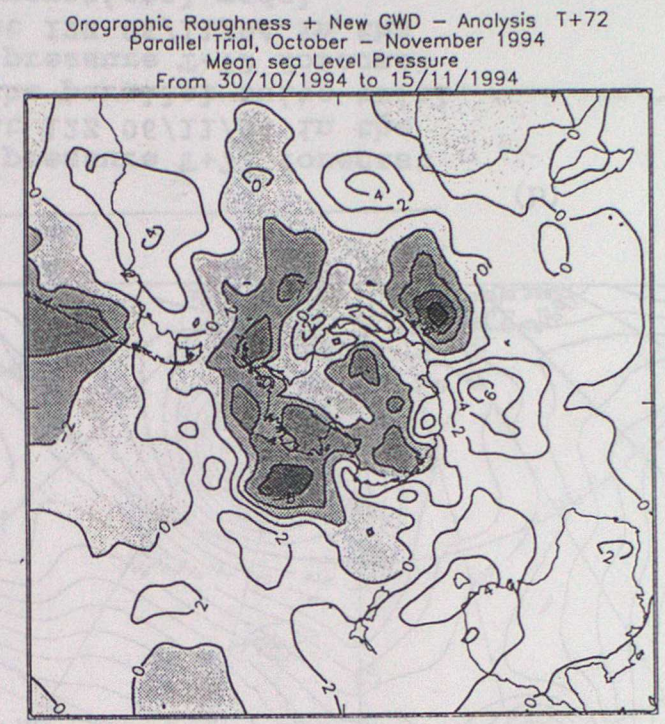
FIGURE 3.17
(a) Global mean sea level pressure operational analysis for 12Z 06/11/94 in the Southern Hemisphere
(b) Global 500hPa height operational analysis for 12Z 06/11/94 in the Southern Hemisphere



(a) (b)

FIGURE 3.18
(a) Global mean sea level pressure T+72 forecast DT12Z 03/11/94 verifying at 12Z 06/11/94 in the Southern Hemisphere from the parallel suite trial
(b) Global mean sea level pressure T+72 forecast DT12Z 03/11/94 verifying at 12Z 06/11/94 in the Southern Hemisphere from operational model





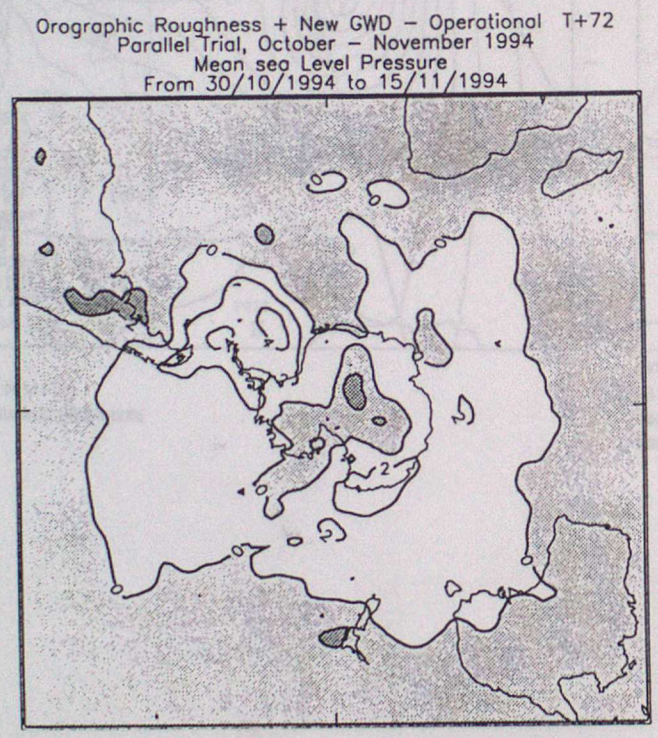
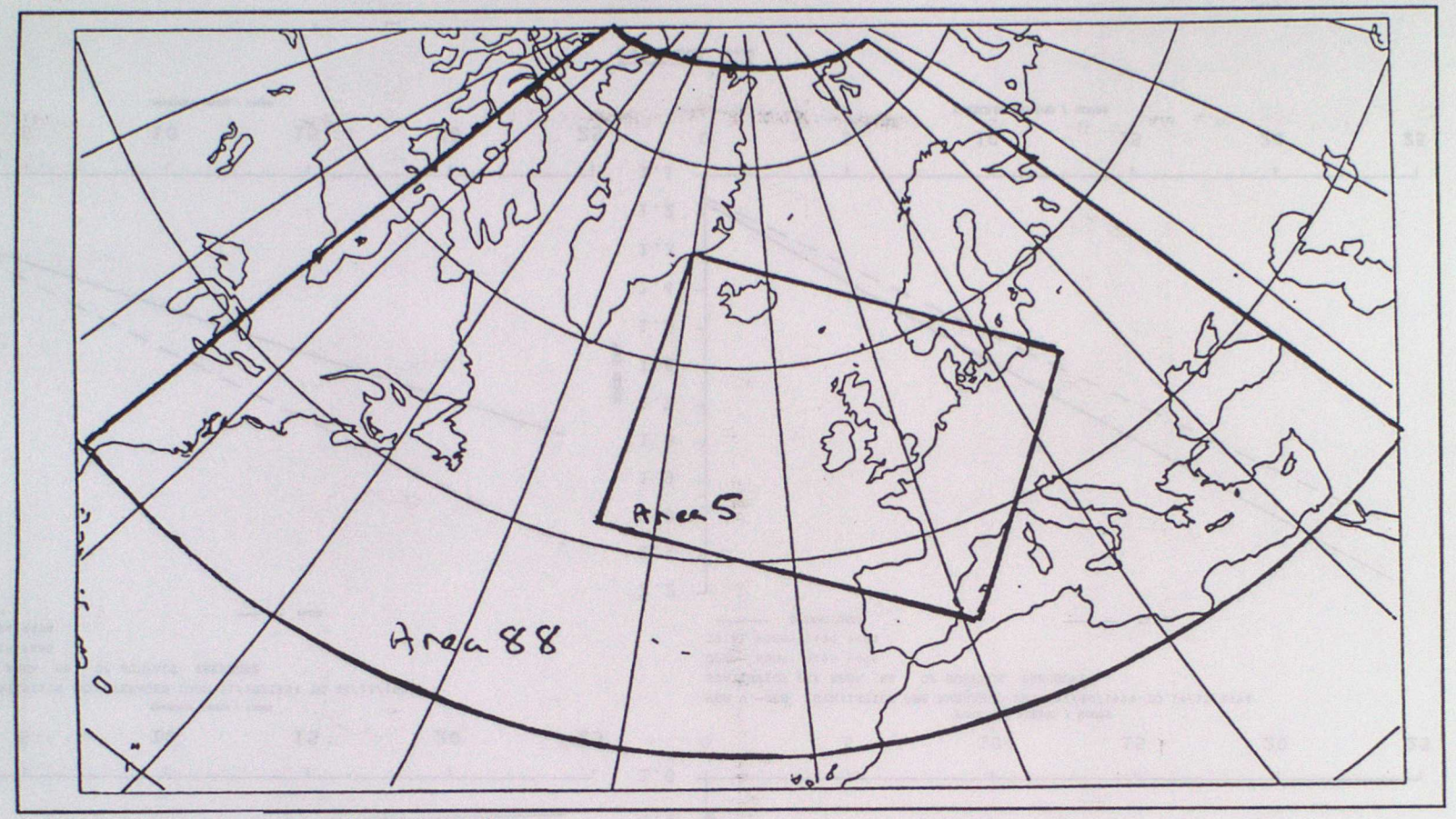


Figure 3.19
T+72 mslp forecast errors against the analysis meaned over the period 12Z 30/10/94 to 12Z 15/11/94 in S.Hem..
(a) operational - analysis
(b) trial - analysis
(c) Differences (trial - operational) in mean sea level pressure at T+72



Verification areas

FIGURE 4.1

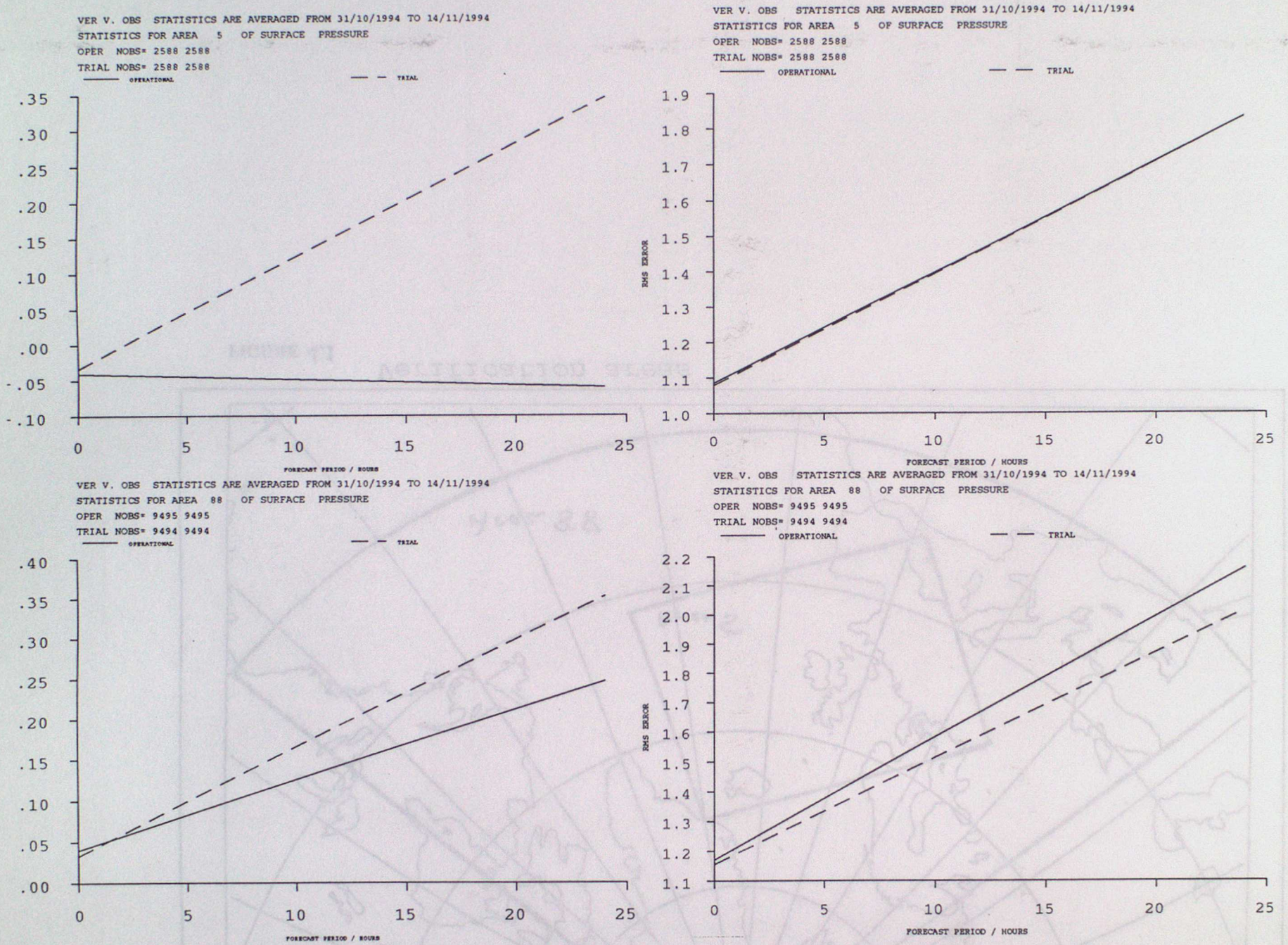

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 5 OF SURFACE PRESSURE
OPER NOBS= 2588 2588
TRIAL NOBS= 2588 2588
OPERATIONAL
TRIAL
MEAN ERROR
.35
.30
.25
.20
.15
.10
.05
.00
-.05
-.10
0
5
10
15
20
25
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 5 OF SURFACE PRESSURE
OPER NOBS= 2588 2588
TRIAL NOBS= 2588 2588
OPERATIONAL
TRIAL
RMS ERROR
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0
5
10
15
20
25
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 88 OF SURFACE PRESSURE
OPER NOBS= 9495 9495
TRIAL NOBS= 9494 9494
OPERATIONAL
TRIAL
MEAN ERROR
.40
.35
.30
.25
.20
.15
.10
.05
.00
0
5
10
15
20
25
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 88 OF SURFACE PRESSURE
OPER NOBS= 9495 9495
TRIAL NOBS= 9494 9494
OPERATIONAL
TRIAL
RMS ERROR
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
0
5
10
15
20
25
FORECAST PERIOD / HOURS

FIGURE 4.2

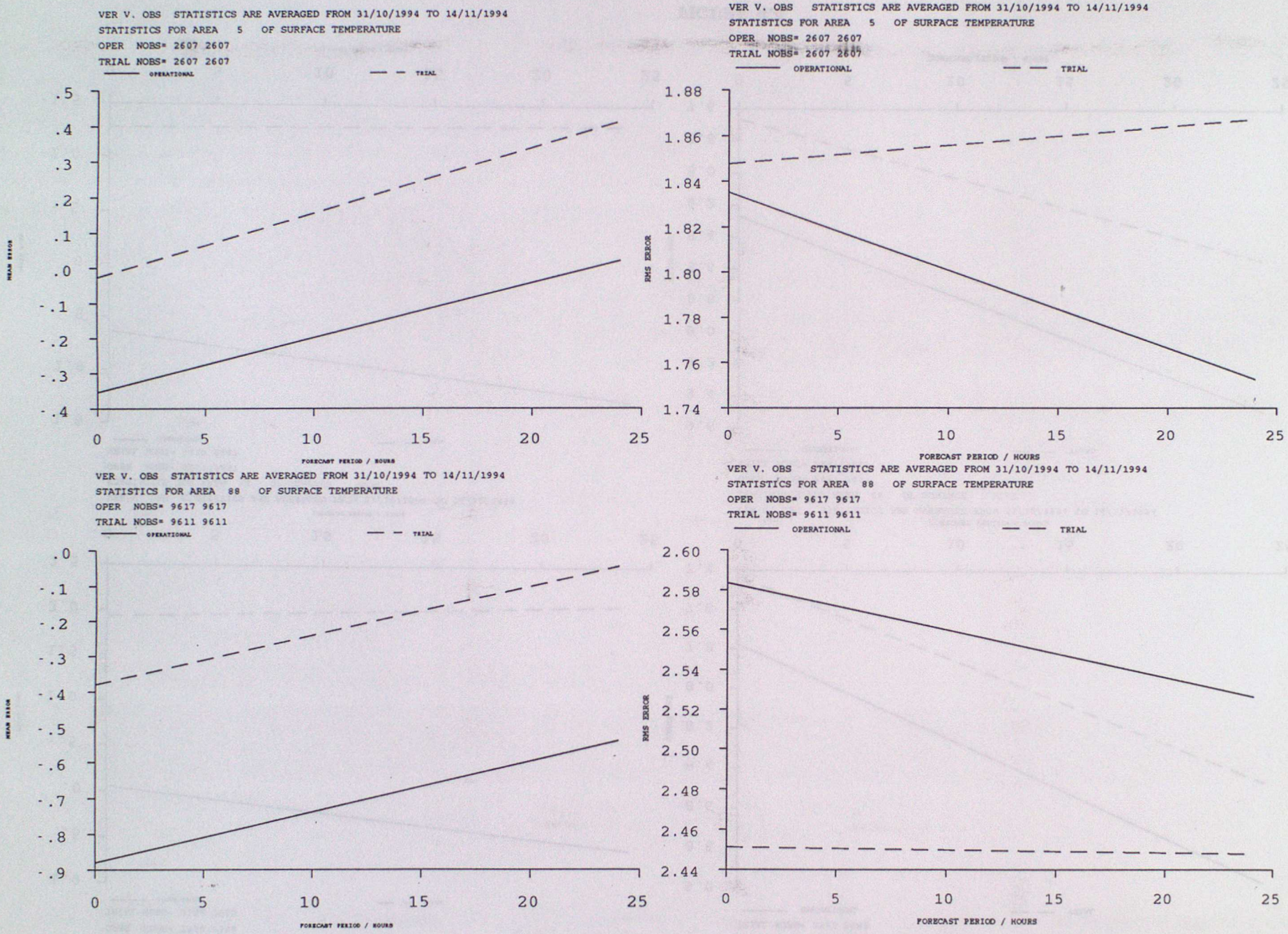

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 5 OF SURFACE TEMPERATURE
OPER NOBS= 2607 2607
TRIAL NOBS= 2607 2607
OPERATIONAL
TRIAL
MEAN ERROR
.5
.4
.3
.2
.1
.0
-.1
-.2
-.3
-.4
0
5
10
15
20
25
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 5 OF SURFACE TEMPERATURE
OPER NOBS= 2607 2607
TRIAL NOBS= 2607 2607
OPERATIONAL
TRIAL
RMS ERROR
1.88
1.86
1.84
1.82
1.80
1.78
1.76
1.74
0
5
10
15
20
25
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 88 OF SURFACE TEMPERATURE
OPER NOBS= 9617 9617
TRIAL NOBS= 9611 9611
OPERATIONAL
TRIAL
MEAN ERROR
.0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
-.9
0
5
10
15
20
25
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 88 OF SURFACE TEMPERATURE
OPER NOBS= 9617 9617
TRIAL NOBS= 9611 9611
OPERATIONAL
TRIAL
RMS ERROR
2.60
2.58
2.56
2.54
2.52
2.50
2.48
2.46
2.44
0
5
10
15
20
25
FORECAST PERIOD / HOURS

FIGURE 4.3

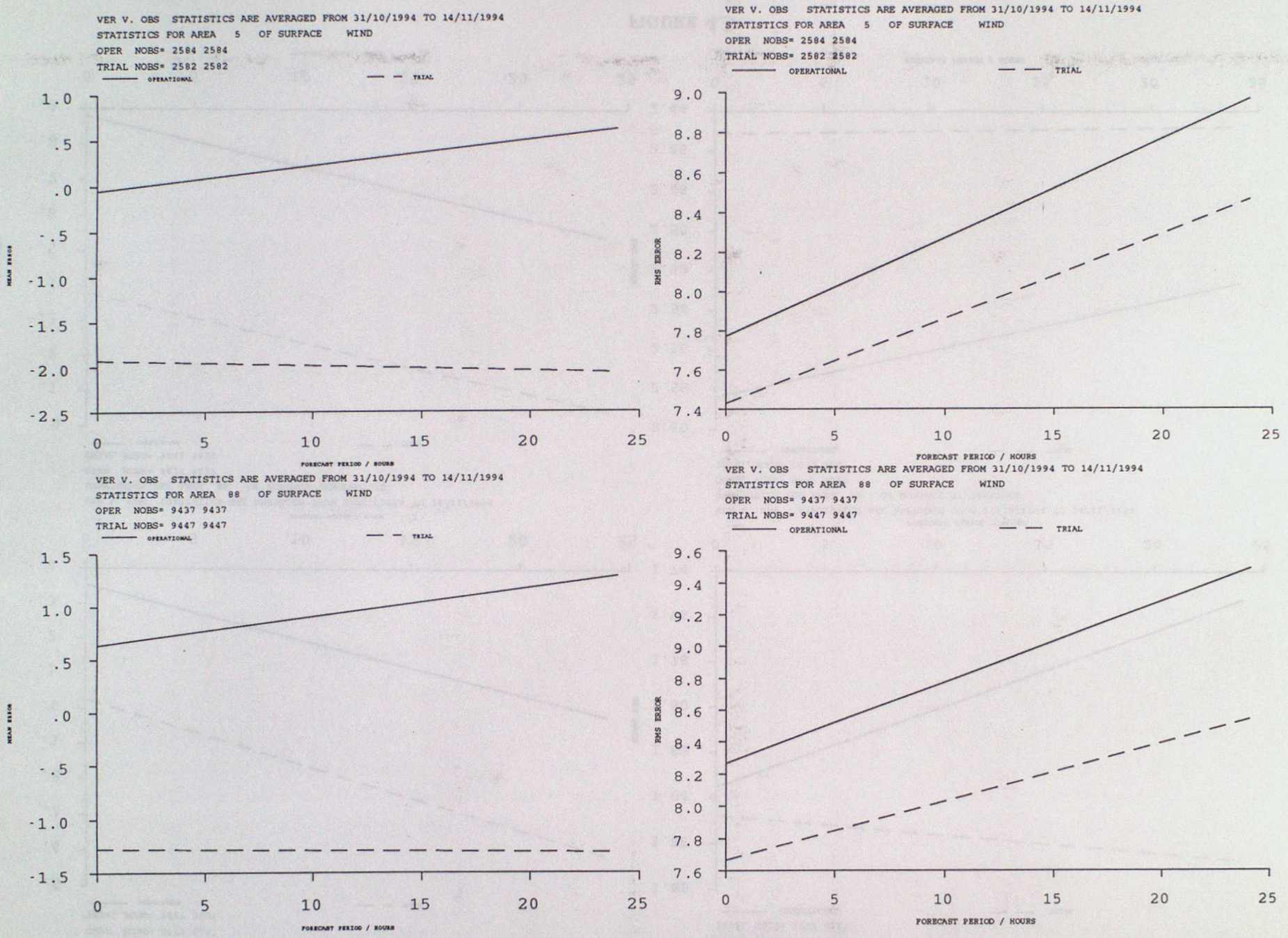
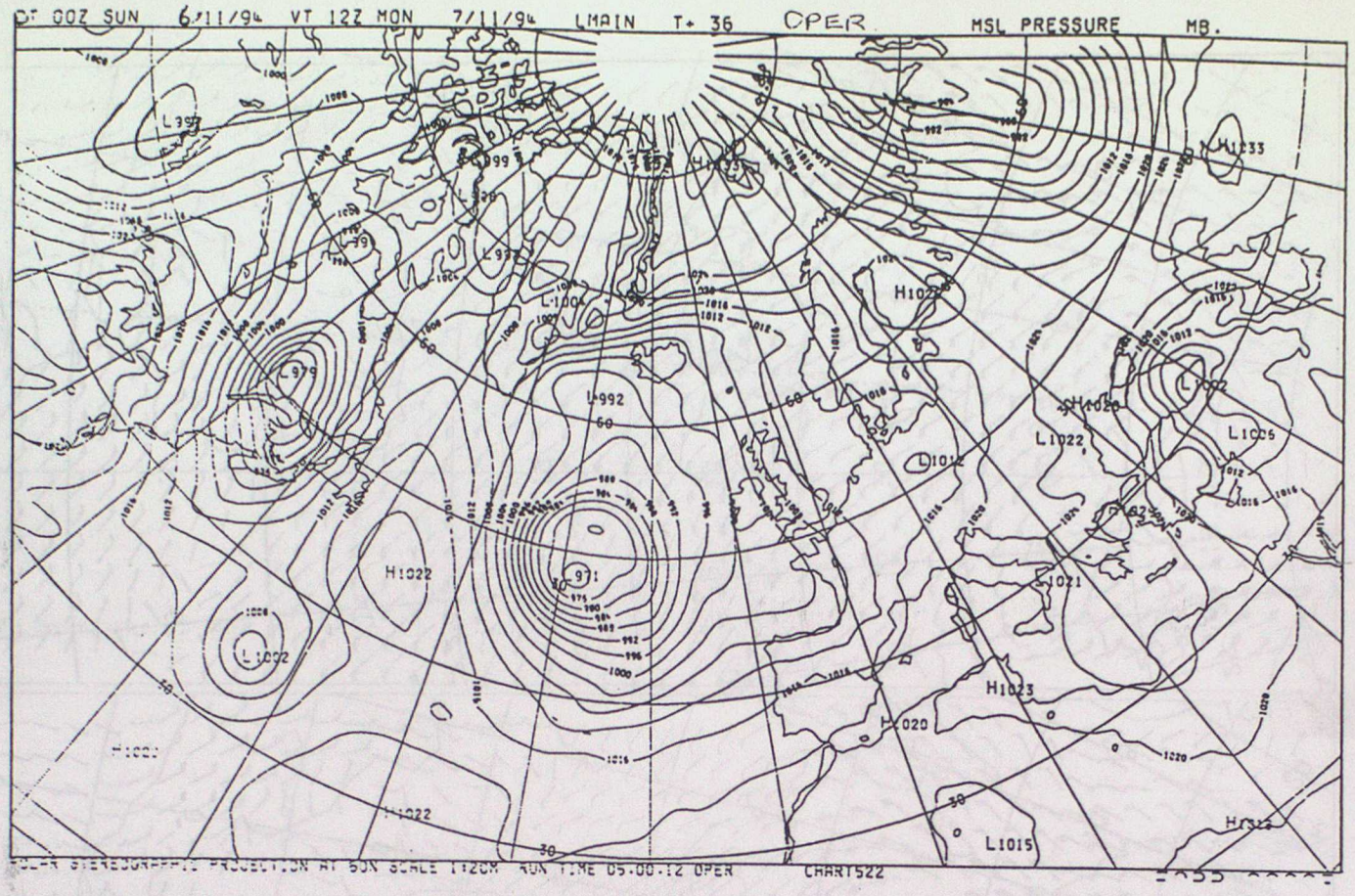
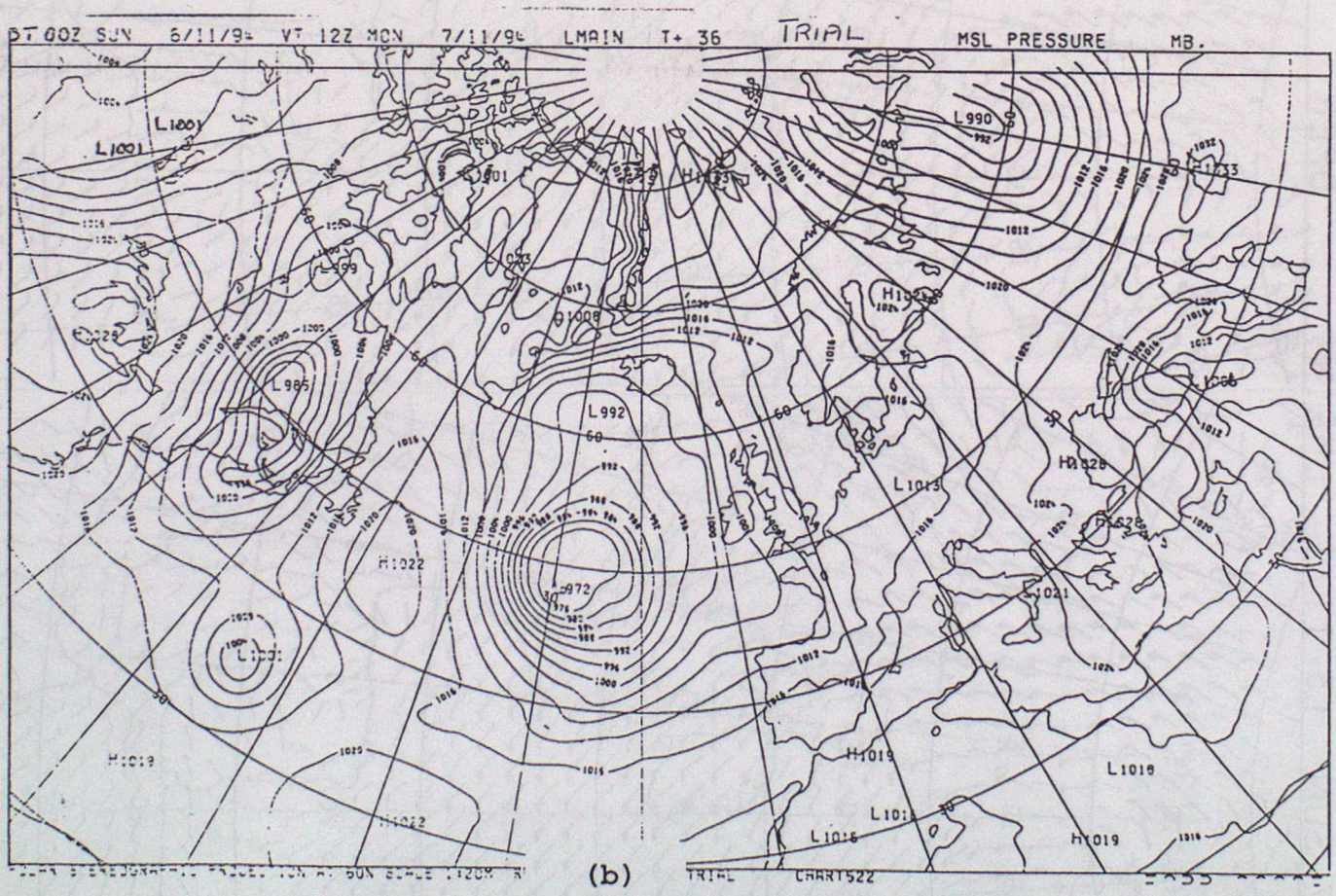

VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 5 OF SURFACE WIND
OPER NOBS= 2584 2584
TRIAL NOBS= 2582 2582
OPERATIONAL
TRIAL
MEAN ERROR
FORECAST PERIOD / HOURS
RMS ERROR
VER V. OBS STATISTICS ARE AVERAGED FROM 31/10/1994 TO 14/11/1994
STATISTICS FOR AREA 88 OF SURFACE WIND
OPER NOBS= 9437 9437
TRIAL NOBS= 9447 9447
OPERATIONAL
TRIAL
MEAN ERROR
FORECAST PERIOD / HOURS
RMS ERROR

FIGURE 4.4



(a)



(b)

FIGURE 5.1 T+36 mean sea level pressure forecast
(a) Operational
(b) Trial (new gravity wave drag/orographic roughness)

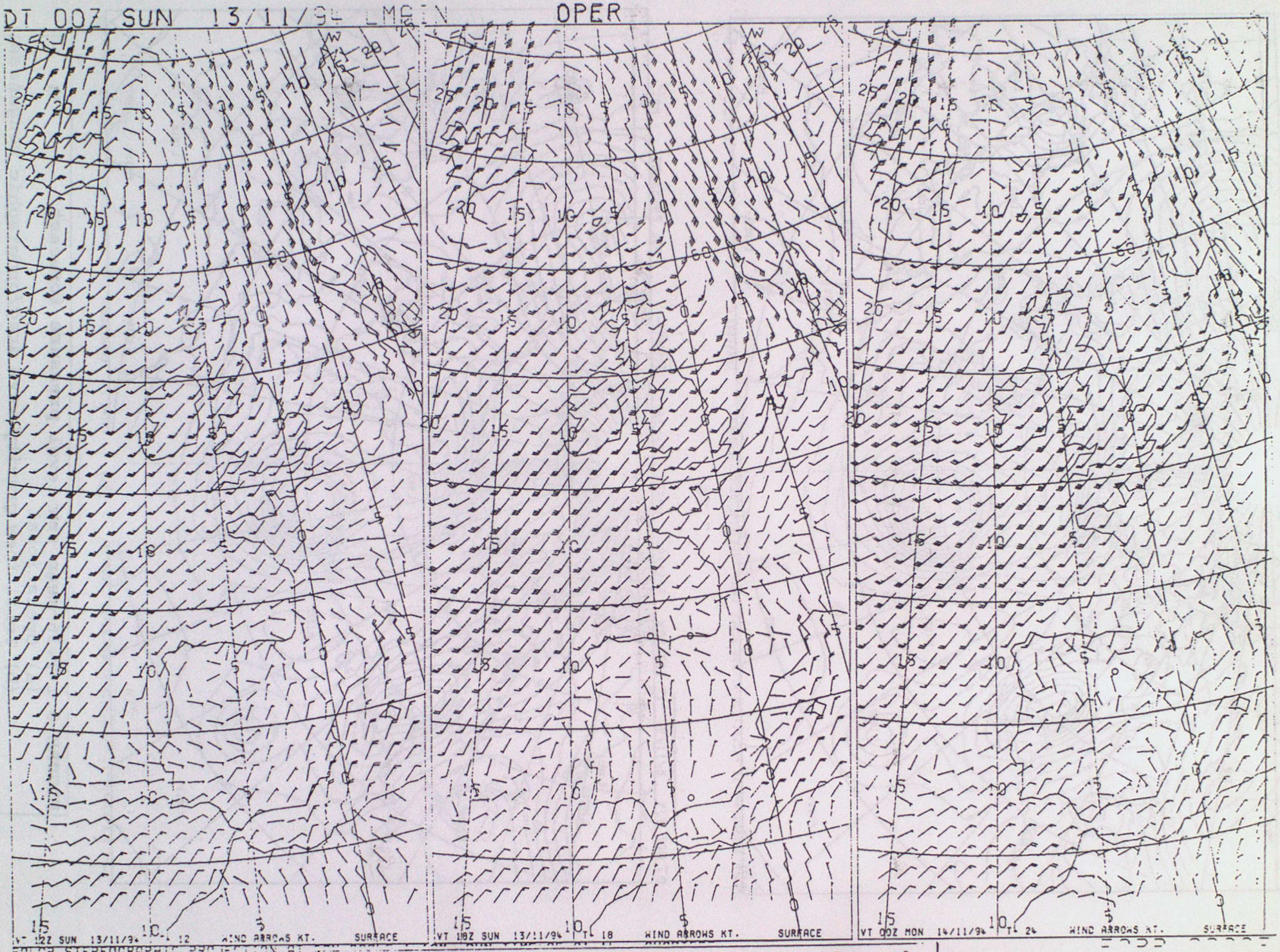


FIGURE 5.2 T+12/18/24 10m wind forecast from the operational model.DT 00Z 13/11/94

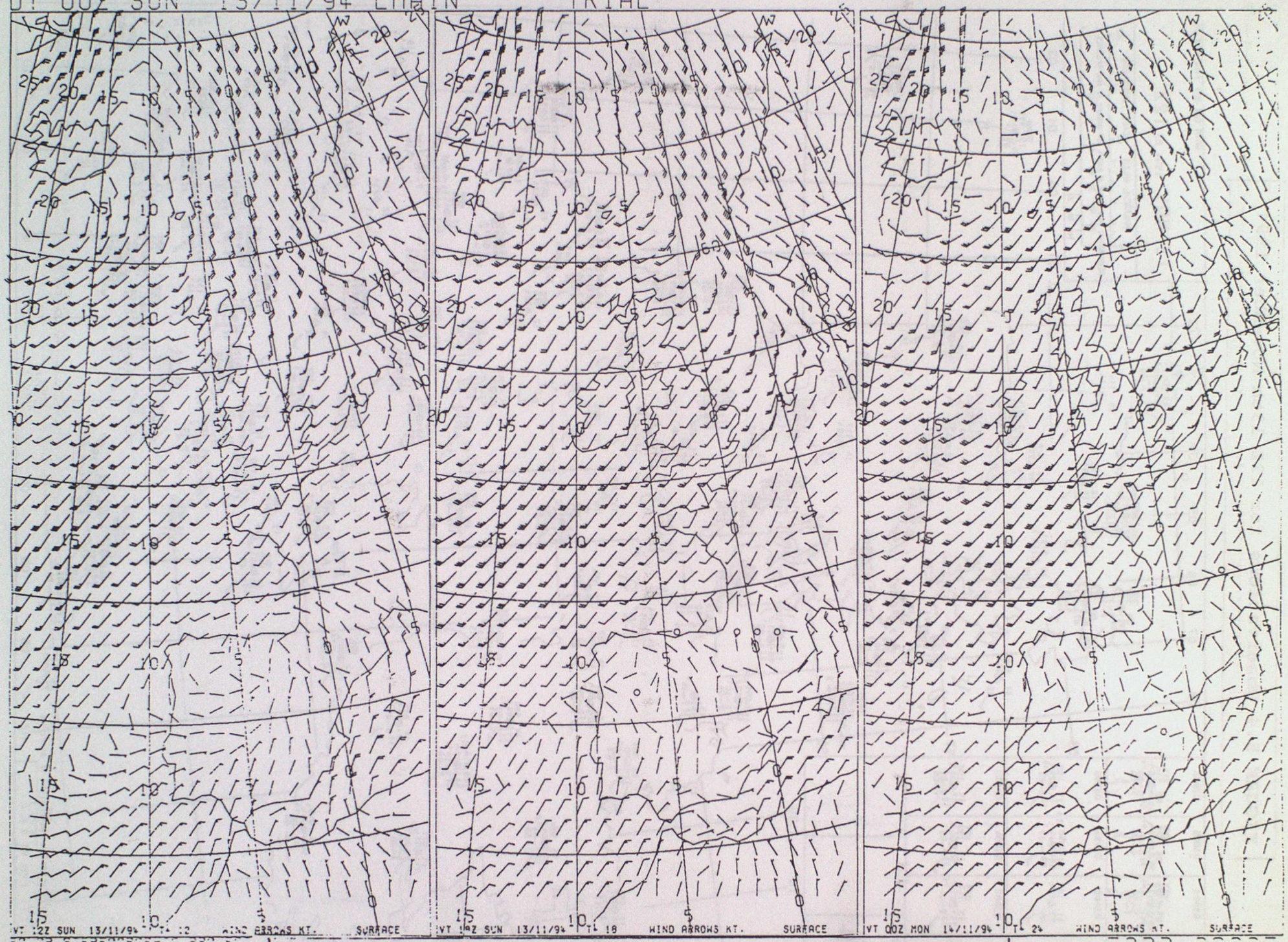


FIGURE 5.3 T+12/18/24 10m wind forecast from the parallel suite trial model.DT 00Z 13/11/94

FIGURE 5.4 Observations for 12Z 13th November 1994

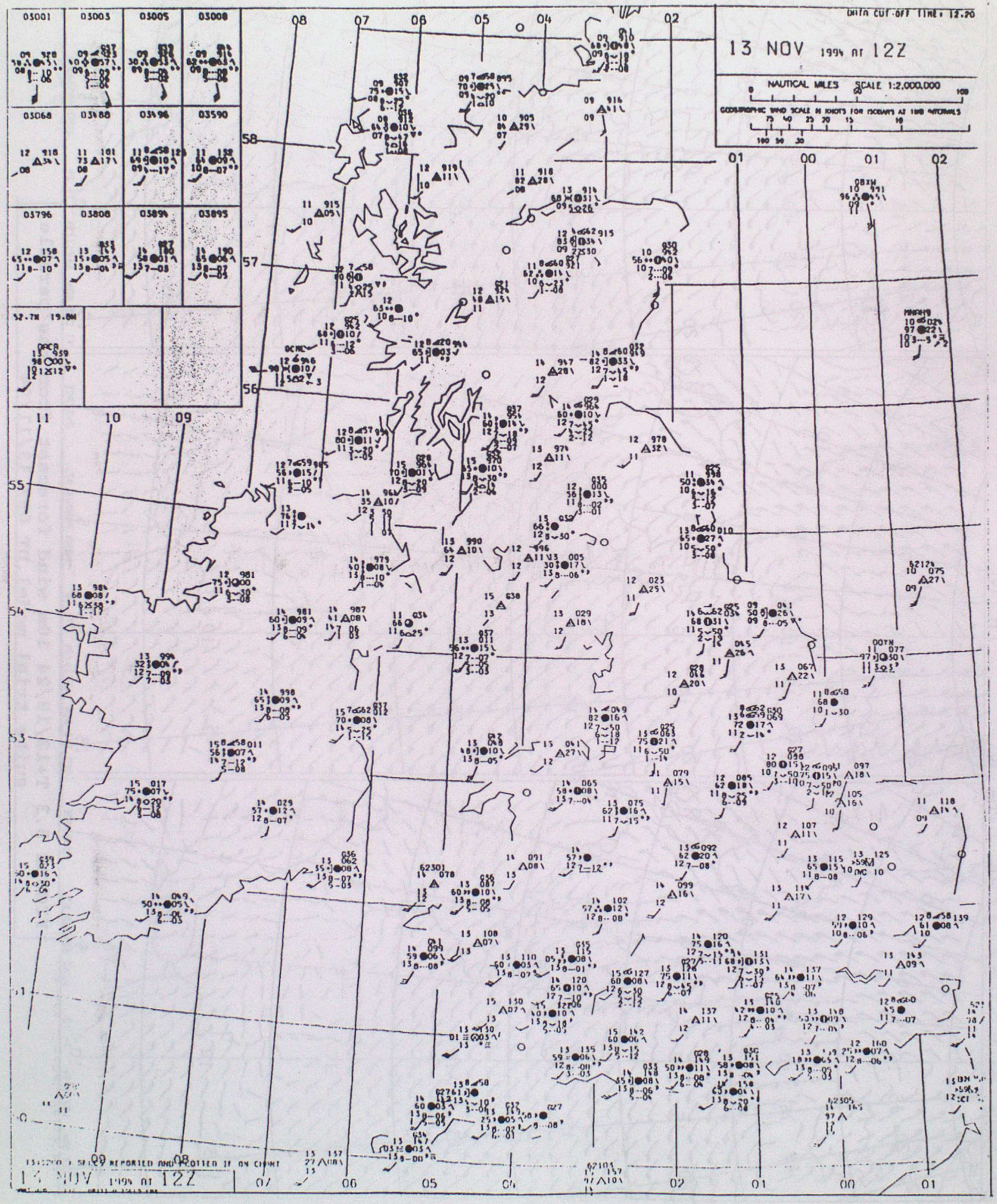
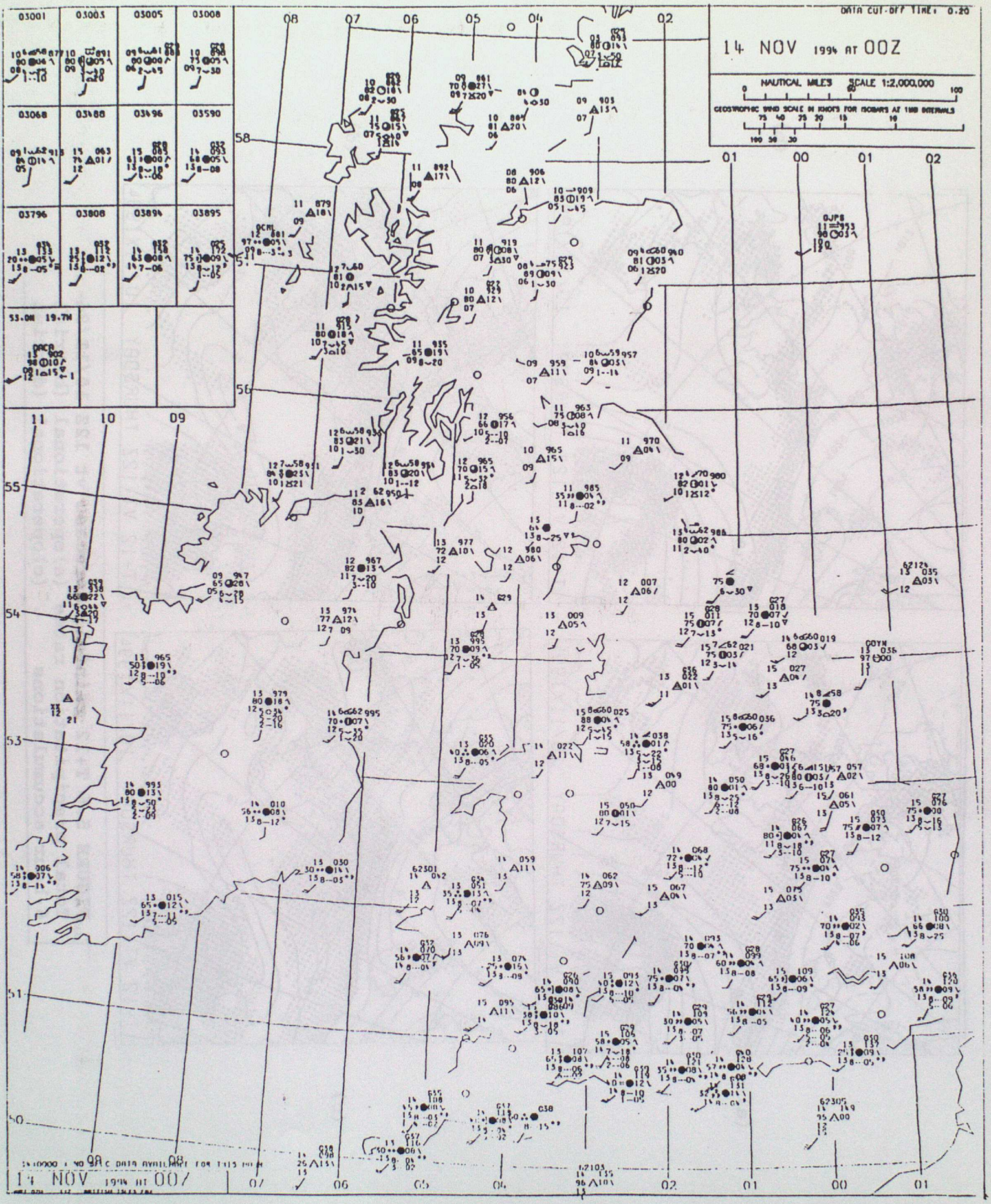
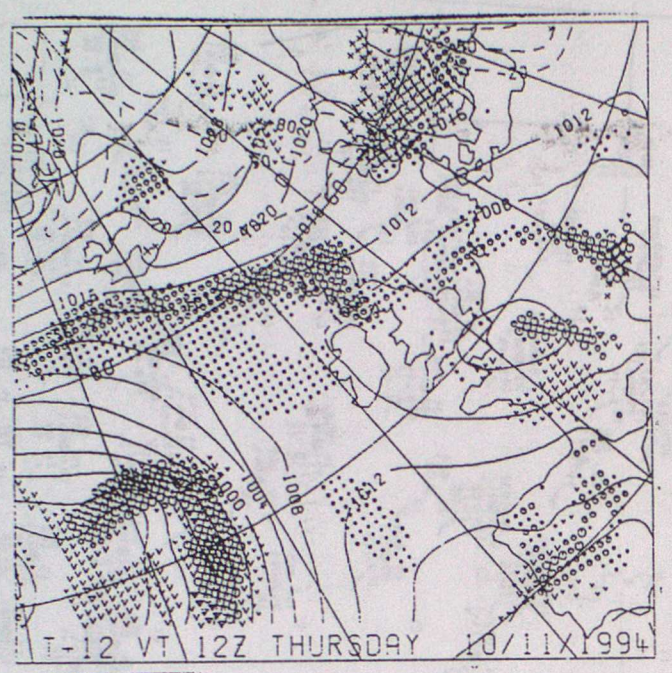


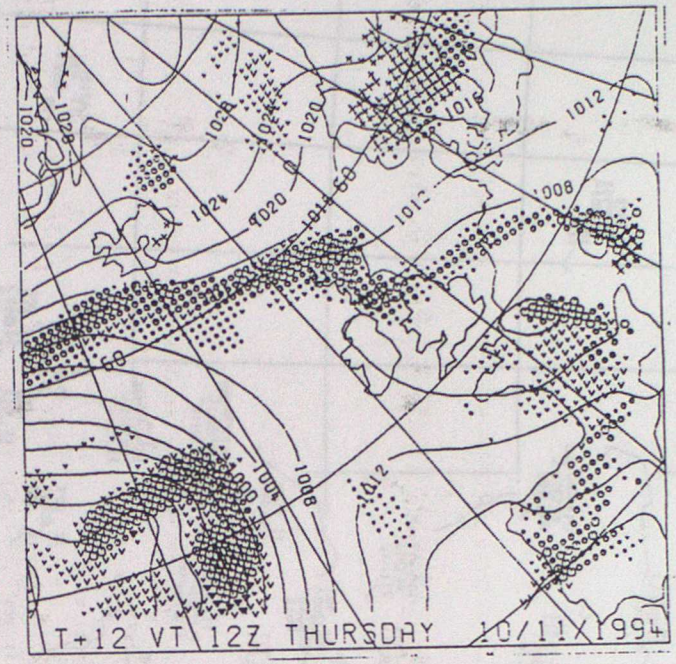
FIGURE 5.5 Observations for 00Z 14th November 1994



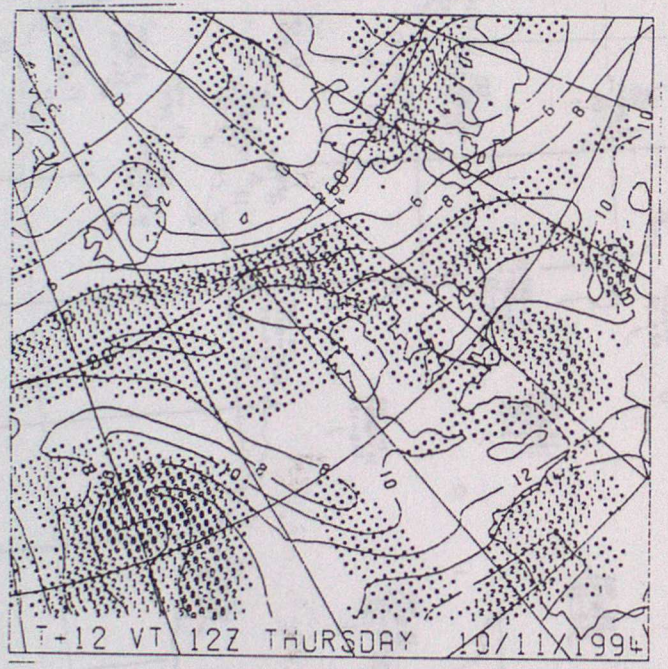
(a)



(b)



(c)



(d)

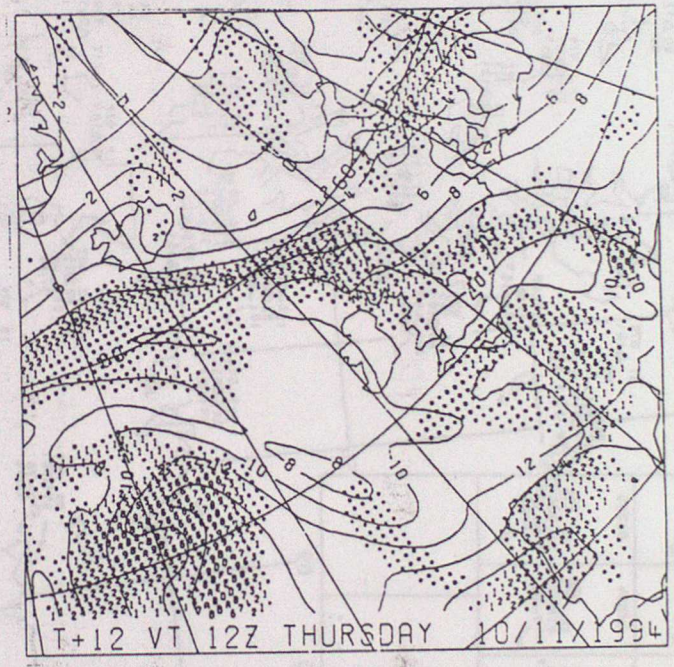
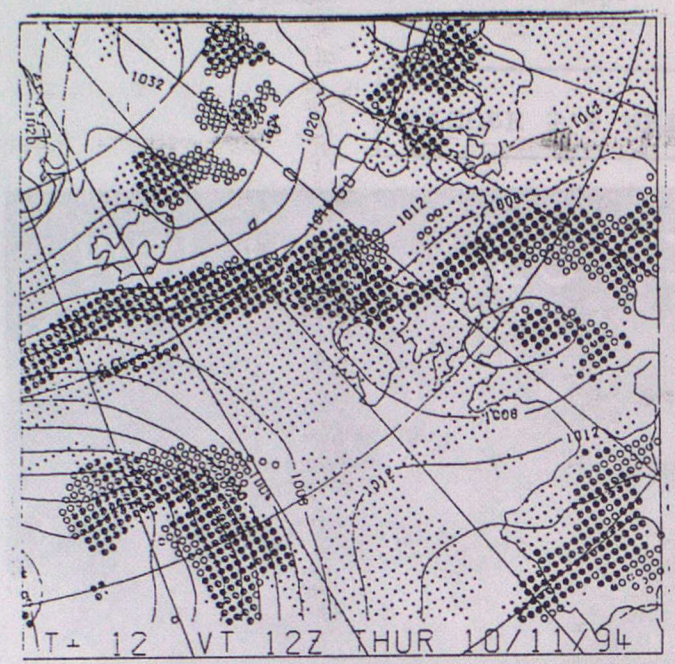
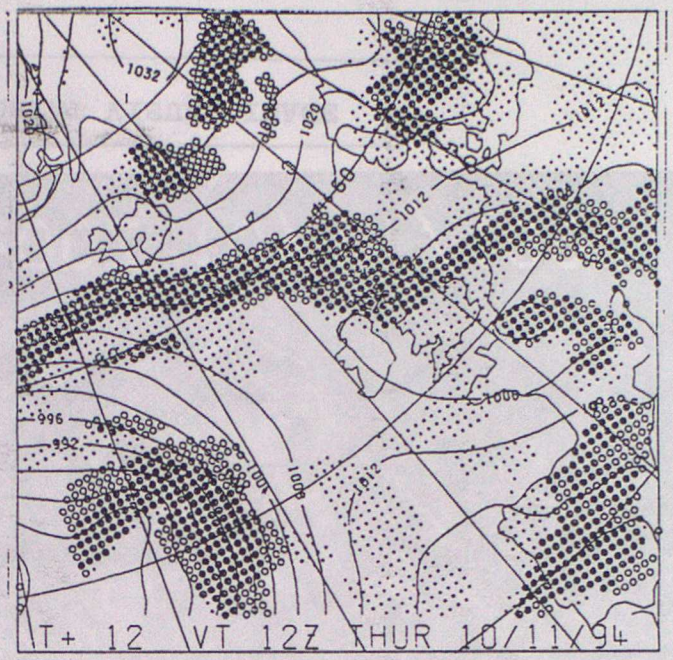


FIGURE 5.6 T+12 rainfall forecast vt 12Z 10/11/94
Total precipitation rates (a) operational (b) trial
6-hour accumulations (c) operational (d) trial

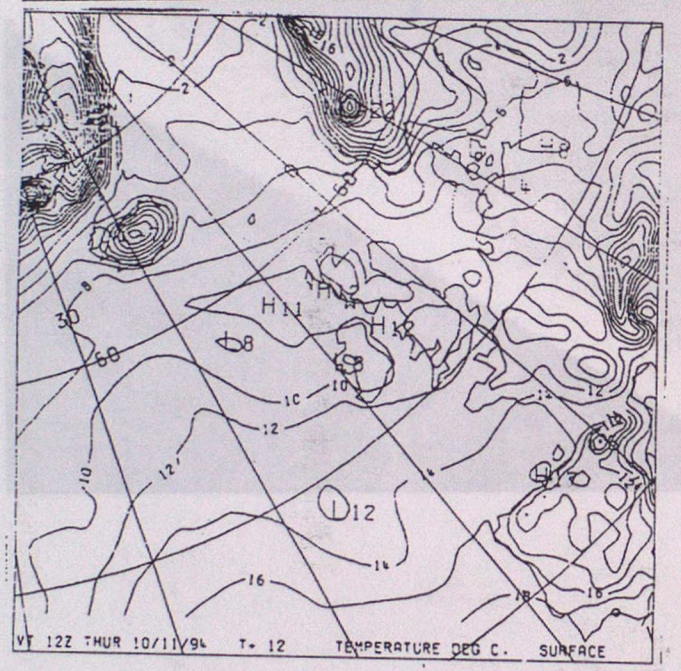
(a)



(b)



(c)



(d)

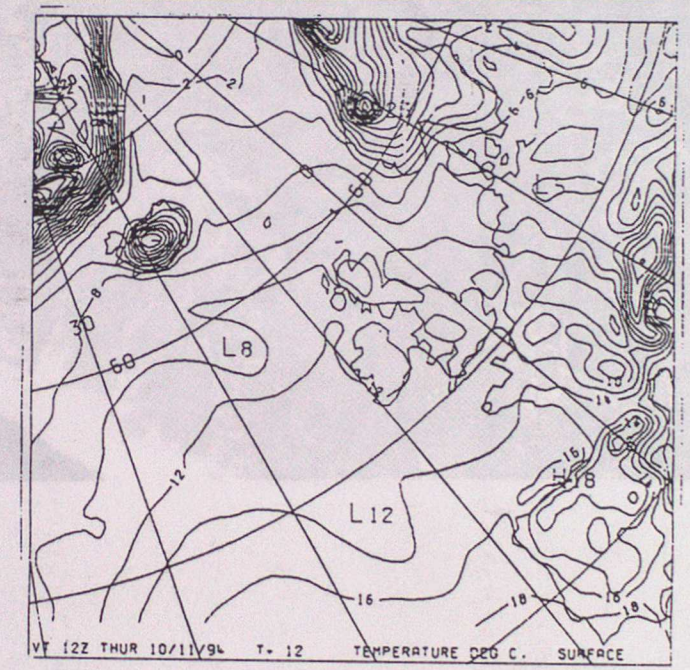


FIGURE 5.7 T+12 forecast vt 12Z 10/11/94
low, medium cloud (a)operational (b)trial
> 4 octas (. = low cloud o.medium cloud)
1.5M Temperatures (c)operational (d)trial

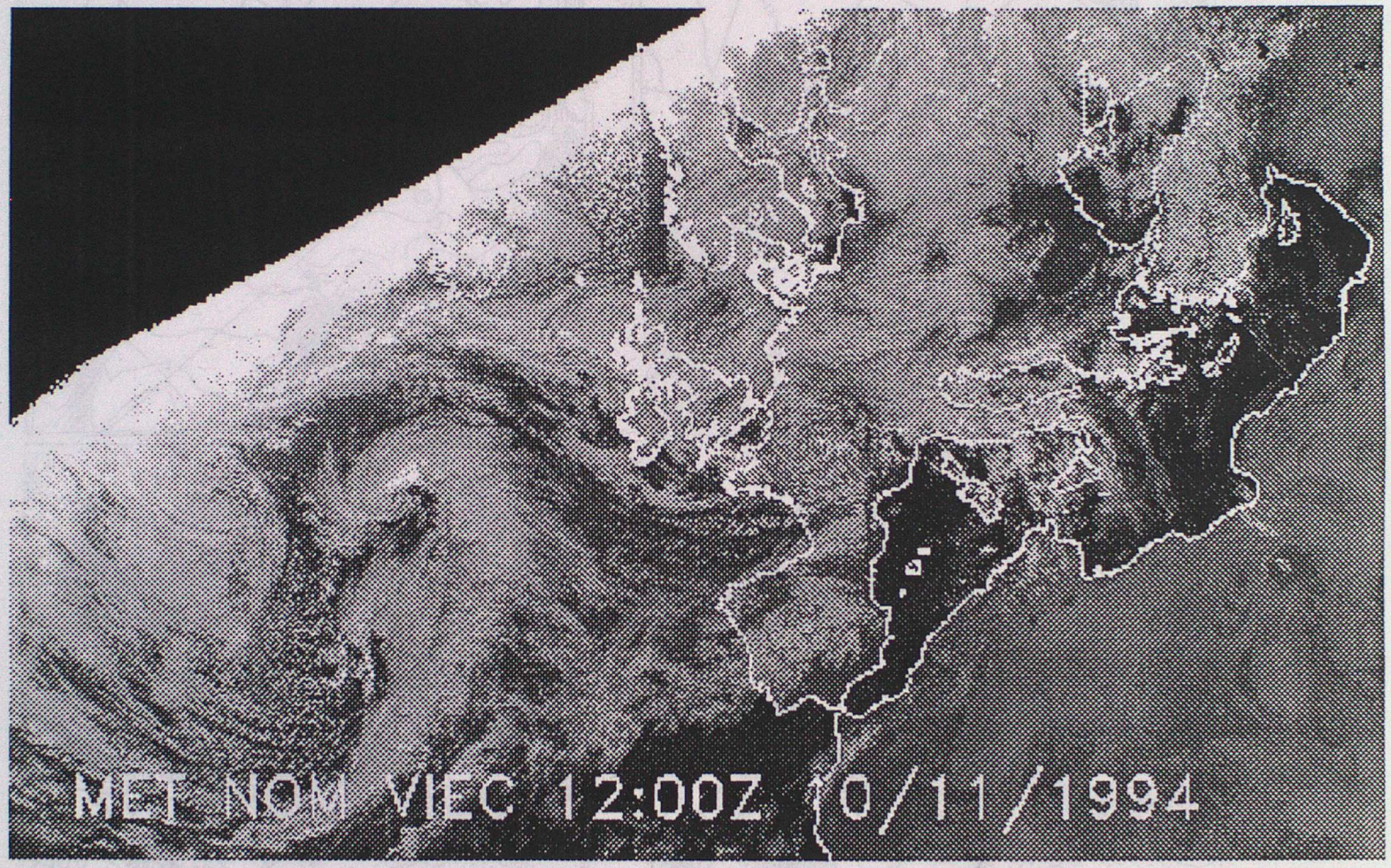


FIGURE 5.8 METEOSTAT VISUAL IMAGE

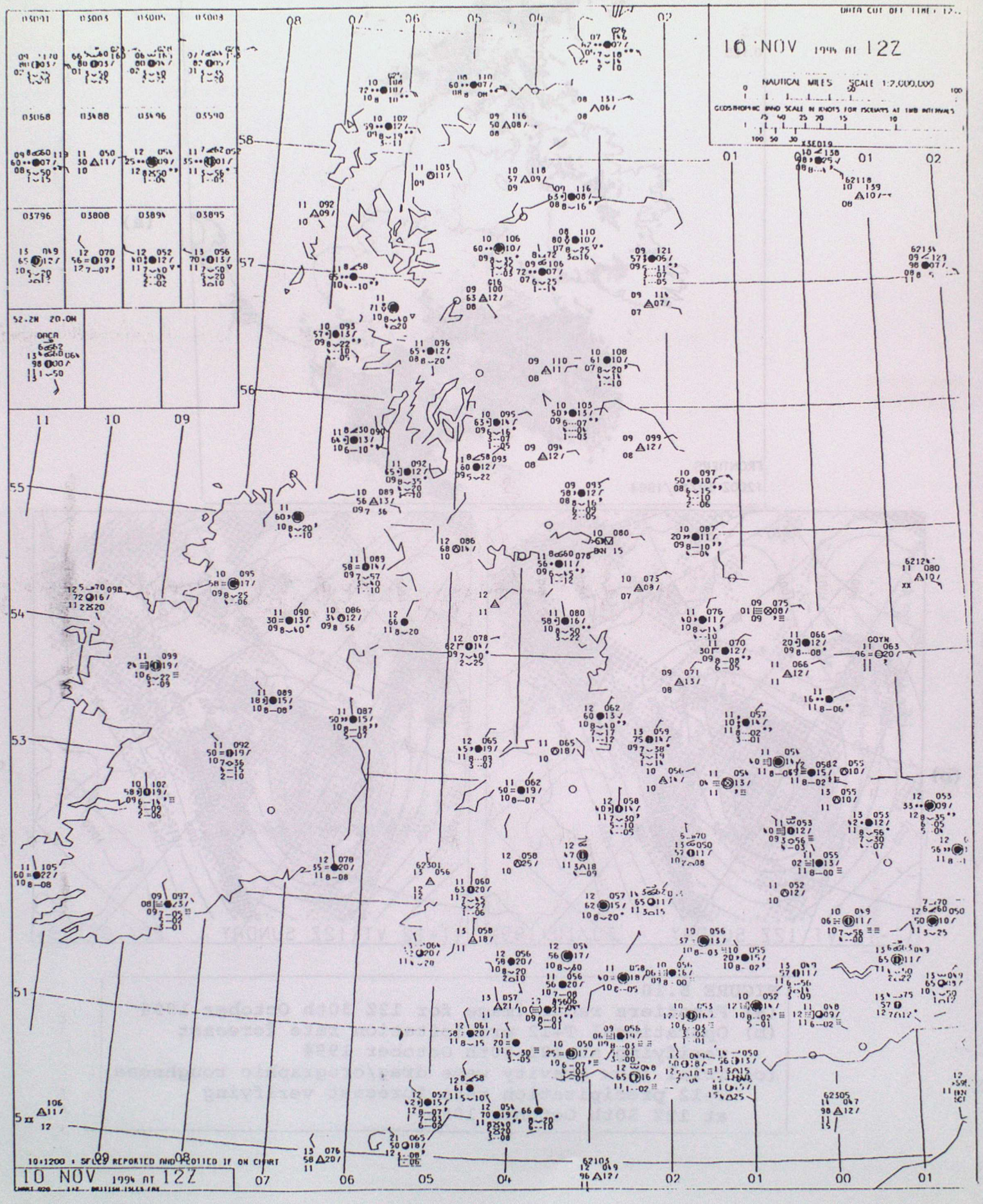
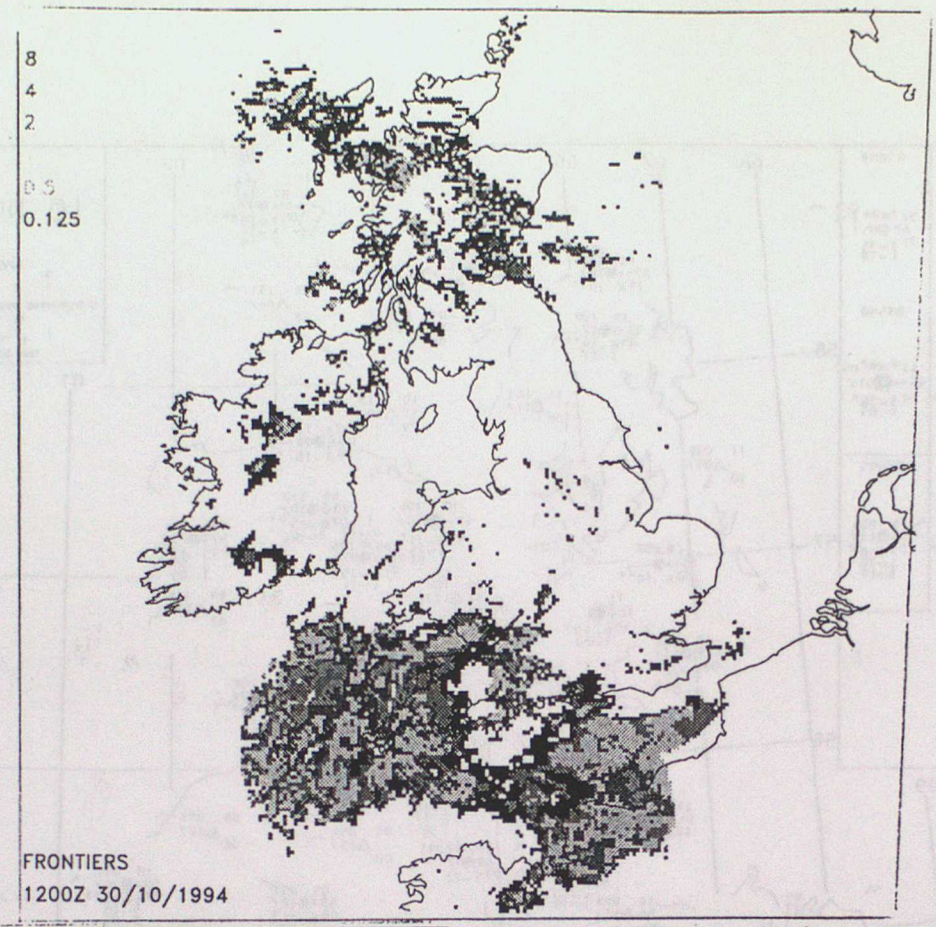
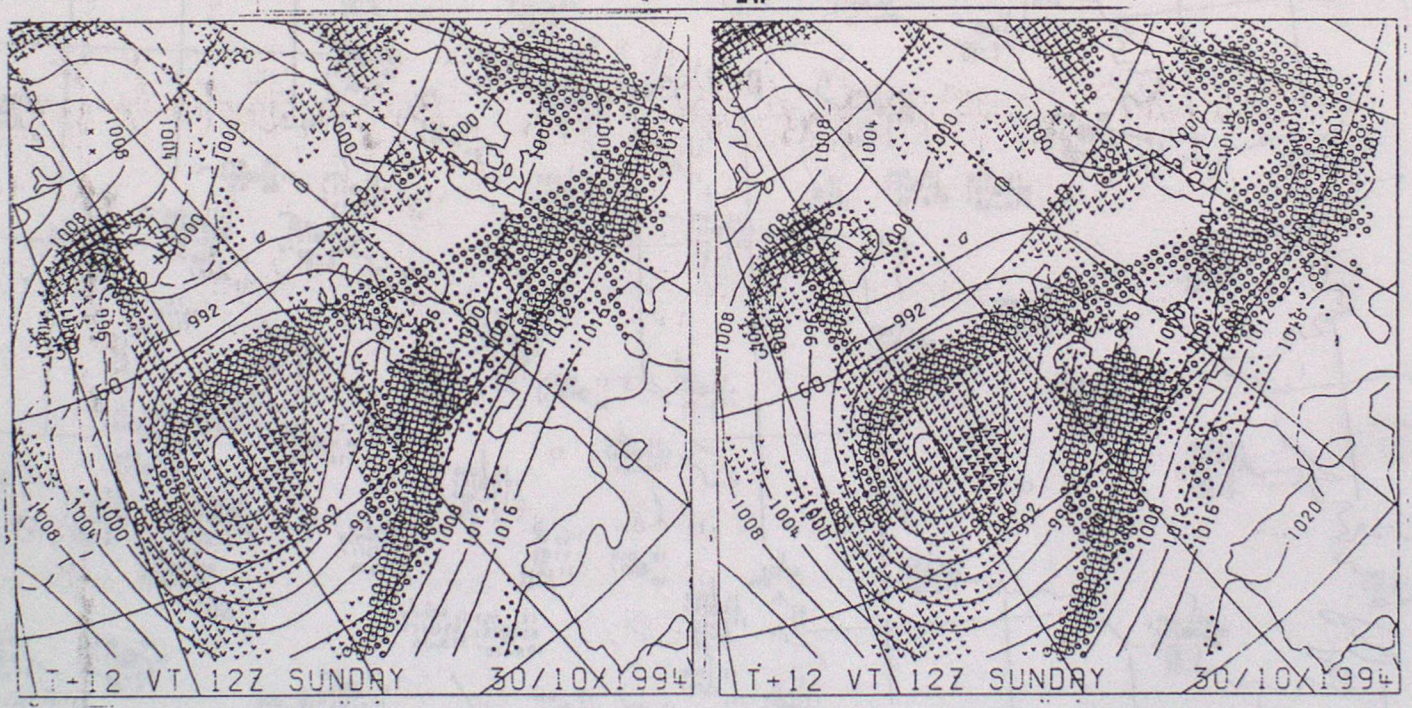


FIGURE 5.9 Observations for 12Z 10th November 1994



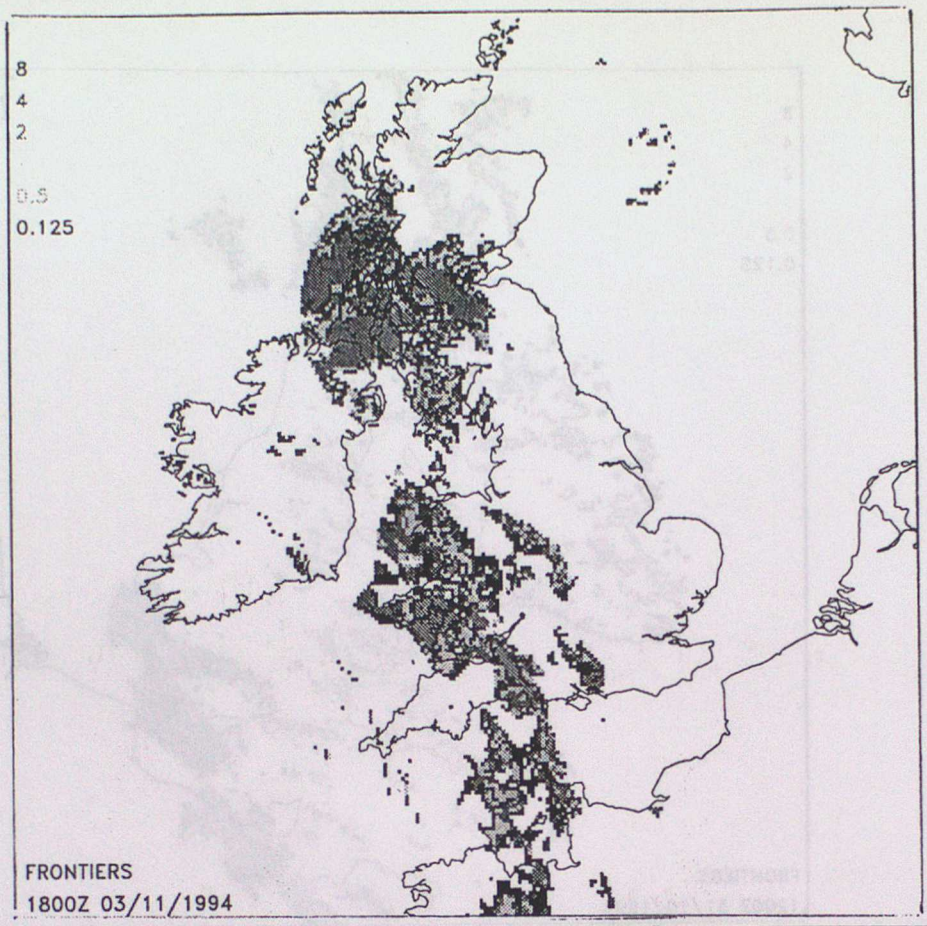
(a)



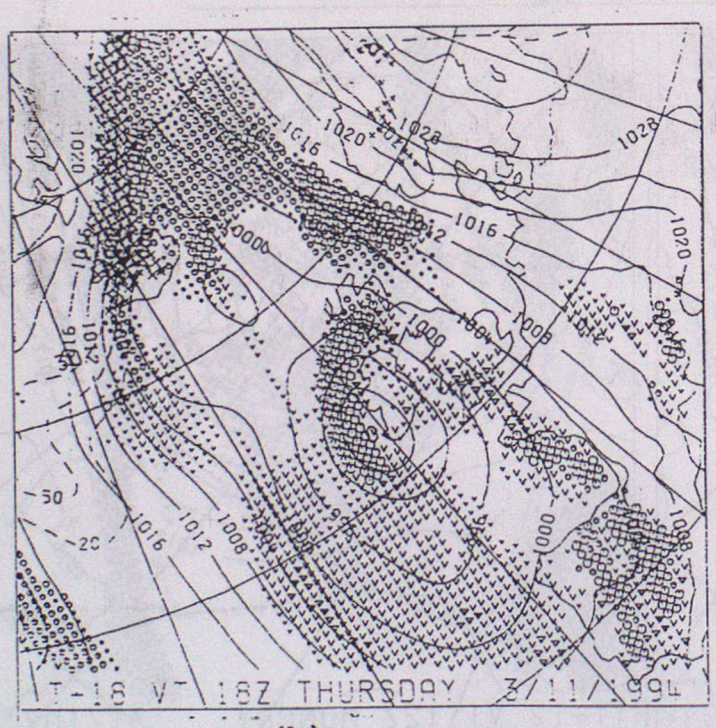
(b)

(c)

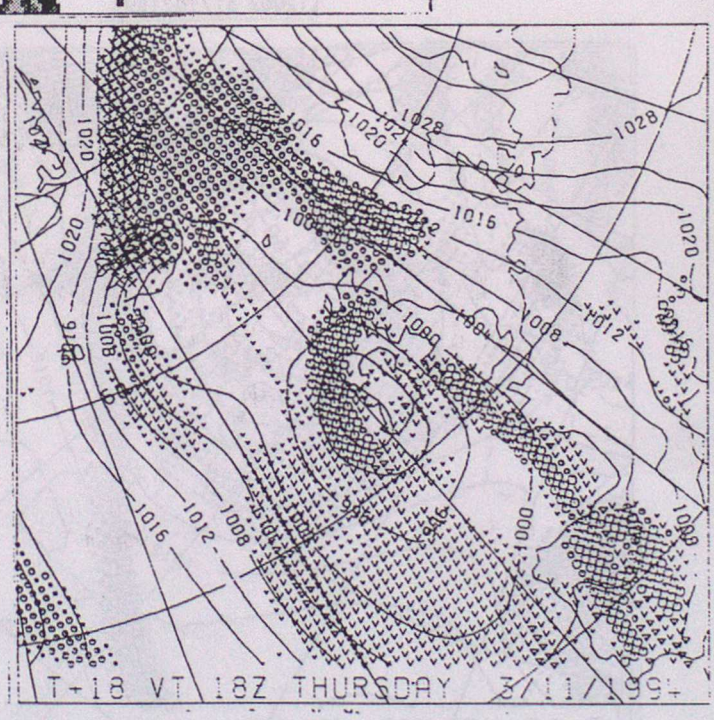
FIGURE 5.10
(a) Frontiers radar image for 12Z 30th October 1994
(b) Operational T+12 precipitation rate forecast verifying at 12Z 30th October 1994
(c) Trial (new gravity wave drag/orographic roughness) T+12 precipitation rate forecast verifying at 12Z 30th October 1994



(a)

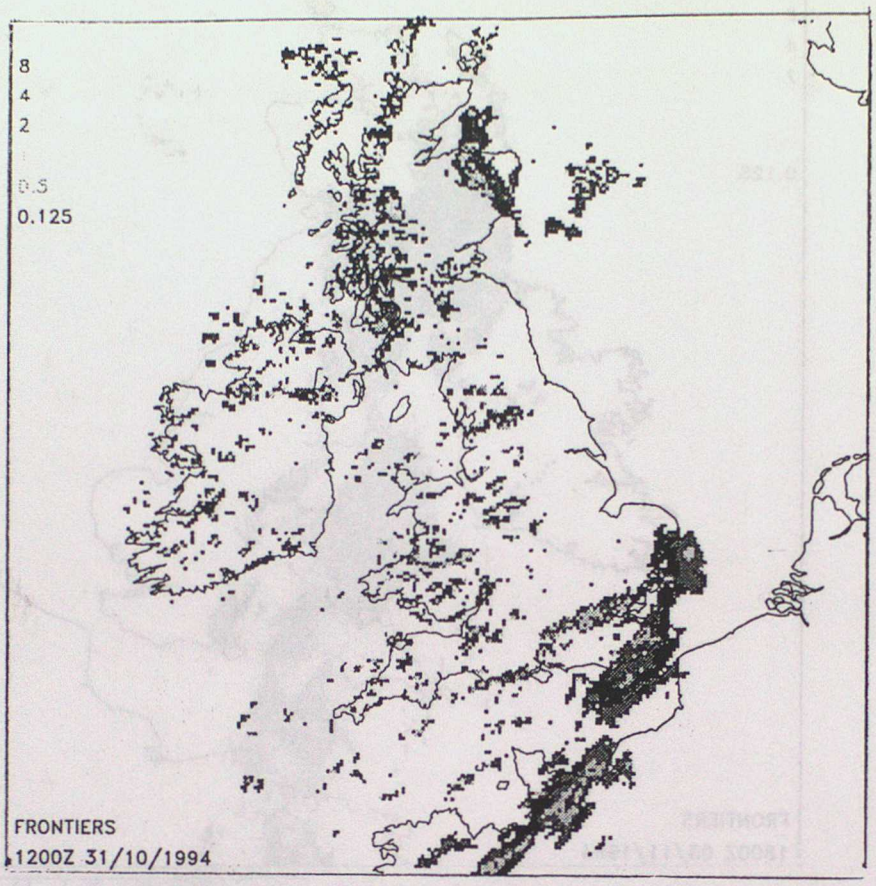


(b)

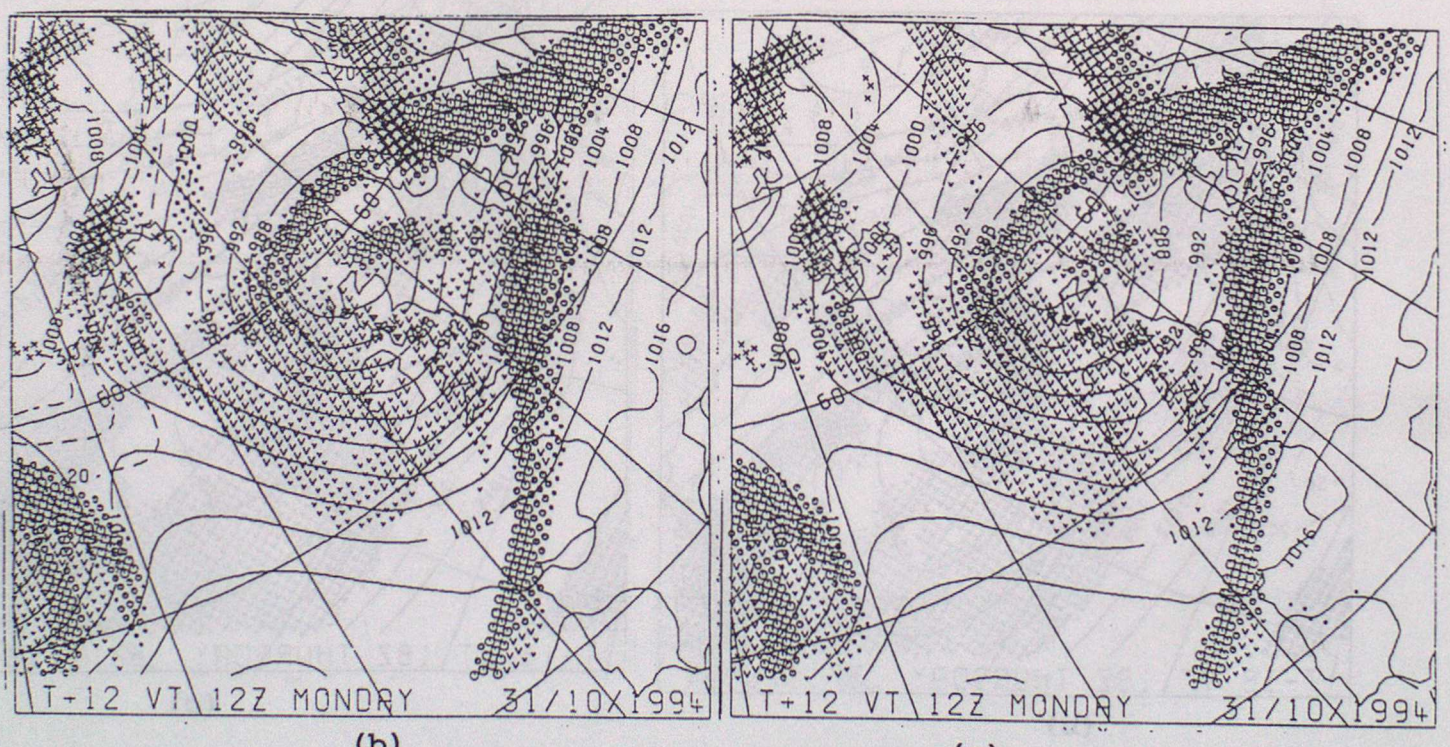


(c)

FIGURE 5.11
(a) Frontiers radar image for 18Z 3rd November 1994
(b) Operational T+18 precipitation rate forecast verifying at 18Z 3rd November 1994
(c) Trial (new gravity wave drag/orographic roughness) T+18 precipitation rate forecast verifying at 18Z 3rd November 1994



(a)



(b) (c)

FIGURE 5.12
(a) Frontiers radar image for 12Z 31st October 1994
(b) Operational T+12 precipitation rate forecast verifying at 12Z 31st October 1994
(c) Trial (new gravity wave drag/orographic roughness) T+18 precipitation rate forecast verifying at 12Z 31st October 1994